RAPTOR RESEARCH

A Quarterly Publication of The Raptor Research Foundation, Inc.

VOLUME 18, NUMBER 2, SUMMER 1984
(ISSN 0099-9059)

CONTENTS

The Raptor Research Foundation, Inc.
Provo, Utah

THE RAPTOR RESEARCH FOUNDATION
(FOUNDED 1966)

****

Persons interested in predatory birds are invited to join the Raptor Research Foundation, Inc. Dues are $15 per year in the U.S., $17 per year outside the U.S., $13 per year for U.S. students, and $15 per year for students outside the U.S.. Add $2 to dues if membership is received after 15 February. The Foundation's journal *Raptor Research* is distributed quarterly to all current members. Subscription price to institutions and nonmembers is the same as regulr membership. Single copies and back issues are available from the Treasurer. A Contributing Membership is $25, a Sustaining Membership is $100, and a Life Membership is $500. All contributions to The Raptor Research Foundation, Inc., are tax-deductible.

Send requests for information concerning membership, subscriptions, special publications, or change of address to the Treasurer. Other communications may be routed through the appropriate Officer or Board member. All inquiries concerning the journal should be addressed to Dr. Clayton M. White, Editor, *Raptor Research*, Department of Zoology, 161 WIDB, Brigham Young University, Provo, Utah 84602, U.S.A.

****

Published quarterly by The Raptor Research Foundation, Inc. Business Office: Dr. Gary E. Duke, Treasurer, Department of Veterinary Biology, 295K Animal Science/Veterinary Medicine Building, University of Minnesota, St. Paul, Minnesota 55108, U.S.A. Printed by Press Publishing Limited, Provo, Utah 84602. Second-class postage paid at Provo, Utah. Printed in U.S.A.

RAPTOR RESEARCH

A QUARTERLY PUBLICATON OF THE RAPTOR RESEARCH FOUNDATION, INC.

VOL. 18 SUMMER 1984 NO. 2

HEPTACHLOR SEED TREATMENT CONTAMINATES HAWKS, OWLS, AND EAGLES OF COLUMBIA BASIN, OREGON

CHARLES J. HENNY, LAWRENCE J. BLUS AND T. EARL KAISER

ABSTRACT - We evaluated organochlorine residues in 12 species of hawks, owls, and eagles from the Columbia Basin of Oregon between 1978 and 1981. Companion studies showed that heptachlor epoxide (HE) induced adult mortality and reduced productivity of the Canada Goose (*Branta canadensis*) and American Kestrel (*Falco sparverius*). In this study, brain tissue from raptors found dead and sample eggs from 90 nests were analyzed for organochlorines. The primary concern was HE that entered raptor food chains through the ingestion of heptachlor-treated seed by their prey. HE residues were detected in eggs from 9 of 10 species and ranged as high as 4.75 ppm (wet wt), but no definite effects of HE on productivity were readily apparent from the limited series of nests. However, the hazard of heptachlor seed treatments to birds of prey was demonstrated by the occurrence of lethal residues of HE in brain tissue of 3 Golden Eagles (*Aquila chrysaetos*) and 1 Rough-legged Hawk (*Buteo lagopus*). Other organochlorine pesticides were present in the eggs and significant relationships were found between DDE and eggshell thickness for the Swainson's Hawk (*Buteo swainsoni*) and Western Screech-Owl (*Otus kennicotti*), although shell thinning (9.6% and 7.4%) was below the generally accepted range where reproductive problems have been known to occur.

The history of heptachlor as a wheat seed treatment to control wireworms in Umatilla and Morrow counties, Oregon, is poorly understood. Through 1970, it was listed in the *Pacific Northwest Insect Control Handbook* (Anon., various dates) after aldrin and dieldrin, with an application rate on seed of 1 oz/bu (about 1,000 ppm). It was not listed in 1971, 1972, and 1973. Then from 1974, heptachlor was listed at 2 oz/bu (about 2,000 ppm). In 1979, heptachlor seed treatments were banned in a 1700 km^2 area near the Umatilla National Wildlife Refuge (NWR), and by 1981, there appeared to be a nearly complete changeover from heptachlor to lindane as a seed treatment in our study area. As of September 1982, production of heptachlor for use as a seed treatment in the United States was prohibited; however, there was a provision for using up existing stocks.

In 1976 and 1977, die-offs of several species of birds occurred in Umatilla and Morrow counties, Oregon. Residues of HE that are considered lethal (Stickel et al. 1979) were found in brain tissue of the Ring-necked Pheasant (*Phasianus colchicus*), California Quail (*Callipepla californica*), Canada Goose, Black-billed Magpie (*Pica pica*), and Golden Eagle (Blus et al. 1979). This history of wildlife mortality associated with heptachlor seed treatment of wheat prompted a detailed study of Canada Geese nesting at Umatilla NWR (Blus et al. 1979), and a study of American Kestrels nesting throughout the region (Henny et al. 1983). Both studies showed heptachlor-induced adult mortality. Furthermore, although HE did not thin eggshells, reduced nesting success was correlated with increased HE residues in eggs of both species. The kestrel was more sensitive to HE residues in eggs than was the Canada Goose (i.e., reduced productivity occurred at > 1.5 ppm [wet wt] in kestrel eggs vs. > 10 ppm in Canada Goose eggs).

We reasoned that Canada Geese were obtaining heptachlor directly from the ingestion of treated seeds; however, the diet of American Kestrels is mainly insects (especially grasshoppers) but includes mice, small birds and some lizards and amphibians (Fisher 1893). Therefore, the presence of HE in kestrel eggs indicated contamination of the food chain of at least one species of hawk.

This study was designed (1) to determine if HE entered food chains of other species of hawks and owls nesting in the region, and (2) to evaluate the success or failure of each nesting attempt in relationship to organochlorine residues in the sample egg collected. The egg data provides insight into residue concentrations that affect reproductive success of the various species although more information of this type is needed. Also, brain tissue of

birds of prey found dead were analyzed to determine if mortality was related to organochlorine contaminants.

METHODS

We collected a sample egg from 90 raptor nests located in Umatilla and Morrow counties, Oregon in 1978-81. The remainder of the eggs were monitored for hatchability and fledging rates. Since a sample egg was collected from each nest for organochlorine analysis, some productivity values were not directly comparable to other published studies. Nest boxes were placed in the region to attract American Kestrels, but Western Screech-Owls and the Northern Saw-whet Owl (*Aegolius acadicus*) also used them. The Burrowing Owl (*Athene cunicularia*) used artificial burrows (Henny and Blus 1981).

The sample eggs were refrigerated until opened. Contents were placed in a chemically cleaned jar and frozen for later analysis. Shell thickness (shell and shell membranes) was measured at 3 sites on each egg equator with a micrometer graduated in units of 0.01 mm. Historical eggshells (pre-1947) were measured at 3 museums in Oregon and Washington. One randomly selected egg from each clutch was measured.

Samples were homogenized and subsamples extracted by a Soxhlet apparatus and cleaned by Florisil-column chromatography. Polychlorinated biphenyls (PCB's) were separated from pesticides by silicic acid column chromatography (Cromartie et al. 1975 and Kaiser et al. 1980). All samples were analyzed for DDE, DDD, DDT, dieldrin, heptachlor epoxide, mirex, oxychlordane, *cis*-chlordane, *cis*-nonachlor, *trans*-nonachlor, endrin, toxaphene, hexachlorobenzene, and PCB's. Additionally, samples in 1978, 1980 and 1981 were analyzed for lindane, samples in 1978 and 1981 for β-BHC, and samples in 1978 for pentachloronitrobenzene (it was not detected).

Residues were quantitated by electron-capture gas-liquid chromatography using either a 1.5/1.95% OV-17/QF-1 or a 1.5/1.95% SP-2250/2401 column. Recoveries from fortified chicken eggs ranged from 83-104%. Residue levels were not corrected for recovery. A few samples from 1978 were analyzed at the Denver Wildlife Research Center (Peterson et al. 1976). Residues in 8% of the samples were confirmed on a Finnigan 4000 series gas chromatograph/mass spectrometer (Kaiser et al. 1980). The lower limit of residue quantification was 0.1 ppm for pesticides and 0.5 ppm for PCB's. For statistical purposes, the lower limit of quantification was divided in half and that value assigned to samples in which the contaminant was not detected. Statistical calculations were not performed unless 75% of the samples contained detectable residues. Contents of eggs were converted to an approximate fresh wet wt by use of egg volume (Stickel et al. 1973); residue concentrations were then expressed on an estimated fresh wet wt basis. A t-test was used to determine significant ($P \leq 0.05$) changes in eggshell thickness. The mean clutch size and mean number of young fledged was not calculated unless ≥ 6 nest records were available.

RESULTS AND DISCUSSION

The largest series of eggs was obtained from the Swainson's Hawk (25 nests) and Long-eared Owl (*Asio otus*) (21 nests), but because the preponderance of data pertain to either 1978 or 1979, a statistical analysis of the residue changes over time was not advisable. A ban on heptachlor seed treatments near the Umatilla NWR in 1979 resulted in an immediate lowering of HE concentrations in kestrel eggs the following year (Henny et al. 1983).

Hawk Eggs. — Heptachlor epoxide was detected in the majority of eggs sampled among the buteos, i.e., Swainson's Hawk (21 of 25, 84%), Ferruginous Hawk (*Buteo regalis*) (9 of 10, 90%), and Red-tailed Hawk (*B. jamaicensis*) (5 of 6, 83%) (Table 1). DDE was detected at about the same frequency as HE in all 3 species: Swainson's Hawk (23 of 25, 92%), Ferruginous Hawk (8 of 10, 80%), and Red-tailed Hawk (5 of 6, 83%). Dieldrin was frequently detected in Swainson's Hawk eggs (13 of 25, 52%), but was virtually absent from the Ferruginous Hawk (0 of 10) and Red-tailed Hawk (1 of 6) eggs.

Residues in sample eggs were tabulated from the highest to the lowest to ascertain if residues influenced nesting success. Although sensitivity to contaminants varies from species to species, we know American Kestrel nesting success declined when HE egg residues increased above 1.5 ppm (Henny et al. 1983). With the Swainson's Hawk, 15 of 21 nests (71%) with $<$ 1.5 ppm HE were successful with 26 young fledged (1.24 per nesting attempt) which was judged good to excellent. (Note: 1 egg was collected which reduced the number fledged). Only 4 nests contained $\geq$ 1.5 ppm HE (2 were successful and fledged 4 young or 1.00 per nesting attempt). Four of 5 Swainson's Hawk nests with the highest DDE residues (5 to 10 ppm) in eggs were successful and produced 10 young (2.00 young/nest). Two successful Swainson's Hawk nests in 1976 contained DDE residues of 4.35 and 7.13 ppm and produced 3 young and 1 young, respectively (Henny and Kaiser 1979). When the 10 nest records from 1976 were combined with 25 nests in this study, regression analysis indicated a significant logarithmic relationship between DDE and eggshell thickness ($Y = 0.393 - 0.022 \log_{10} X$, $r = -0.40$, $P < 0.02$). The same method showed no significant relationship between HE and eggshell thickness ($Y = 0.393 + 0.002 \log_{10} X$, $r = 0.04$, $P > 0.05$). Eggshell thickness ($\bar{X} \pm SE$) during this study was 0.387 ± 0.007 mm which was 9.6% thinner ($P < 0.01$) than the pre-DDT era (before 1947) mean of 0.428 ± 0.005 mm in the Pacific Northwest (Henny and Kaiser 1979). This amount of thinning was less than the generally accepted 18-22% range where reproductive problems occur (Lincer 1975).

Bechard (1981) collected a sample egg from 6 Swainson's Hawk nests in nearby southeastern Washington in 1977 and 1978. At least 1 young was fledged from each nest. Low DDE residues (ppm wet wt) were reported in 5 eggs (0.20, 0.68, 1.2, 1.4, 2.9) and low HE residues in 2 eggs (0.11, 0.35).

Neither the Ferruginous nor the Red-tailed Hawk eggs contained HE above 1.5 ppm (the effect zone observed for the American Kestrel), and DDE residues were generally low. Shell thickness for the Red-tailed Hawk was identical (0.420±0.017 mm) to pre-1947 thickness from the northern prairies (Anderson and Hickey 1972); whereas, the small series of Ferruginous Hawk eggs showed a significant ($P < 0.01$) shell thickness increase (0.485±0.006 mm, n = 10 vs. 0.451± 0.008 mm, n = 14) in comparison to eggs collected in Oregon and Washington before 1947. Ferruginous Hawk eggs collected from 6 nests in southcentral Idaho in 1979 contained low residues (ppm wet wt) of DDT and its metabolites (highest value 0.65) and low residues of HE (highest value 0.10) (Thurow et al. 1980). HE residues in Swainson's and Ferruginous Hawk eggs from this study were higher than reported from eggs collected in adjacent states during the same time period.

Four Northern Harrier (*Circus cyaneus*) eggs and 2 Prairie Falcon (*Falco mexicanus*) eggs all contained HE and DDE (Table 1).

Owl Eggs. — Heptachlor epoxide was detected

Table 1. Clutch size, fledging success, eggshell thickness, and organochlorine residues (ppm wet wt) in eggs of hawks nesting in Umatilla and Morrow counties, Oregon, 1978-80.

Year	Clutch size[a]	Fledged	Shell Thickness (mm)	HE	OXY	DDE	Dieldrin	HCB	TRNO
Swainson's Hawk									
1979	4	1	0.480	2.95	0.31	0.76	0.49	0.19	0.10
1978[b]	4	3	0.383	2.93		2.16			
1979	2	0	0.372	2.82	0.23	10.34			1.03
1979	3	0	0.360	2.52	0.28	1.15	0.52	2.62	0.58
1979	2	0	0.418	1.42		0.21			
1979	2	1	0.391	1.31	0.14	1.87			0.14
1979[c]	4	3	0.365	1.20	0.11	10.41	0.11		
1979	4	3	0.430	0.93		0.66	0.14		
1979	3	0	0.417	0.67		0.21	0.45		
1980	?	1	0.429	0.64	0.13		0.10		
1979	3	0	0.353	0.50		0.45			
1979[c]	4	3	0.335	0.36		8.74	1.34		
1979[d]	3	0	0.378	0.35	0.13	1.28	0.33		
1979	3	0	0.398	0.26			0.10		
1980	2	0	0.351	0.25		0.28	0.17		
1979[e]	4	3	0.370	0.23		7.50	0.10		
1979	3	1	0.359	0.23		1.41			
1979	3	1	0.388	0.19		2.66	0.15		
1979	4	2	0.377	0.14		2.96			
1979	3	1	0.430	0.13		0.56			
1978[b]	?	1	0.371	0.10		0.15			
1978[b]	3	1	0.346			5.00			
1979	4	2	0.381			1.56			
1979	3	1	0.404			1.32	0.13		
1979[f]	4	2	0.397			0.23			
	3.22[g]	1.20[g]	0.387[g]	0.38[h]		0.98[h]			

(Table 1 Continued)

(Table 1 Concluded)

Year	Clutch size[a]	Fledged	Shell Thickness (mm)	HE	OXY	DDE	Dieldrin	HCB	TRNO
Ferruginous Hawk									
1978[b]	4	3	0.475	1.32		3.88			
1979	2	0	0.493	1.08	0.12	2.25			
1979	2	0	0.509	0.56	0.11			0.28	
1978[b]	2	1	0.457	0.49		1.05			
1979	4	2	0.455	0.40		0.65			
1979	4	2	0.512	0.38					
1978[b]	4	3	0.497	0.17		0.29			
1978[b]	4	0	0.477	0.14		0.10			
1978[b]	5	0	0.496	0.10		0.32			
1980	4	2	0.475			1.31		0.30	
	3.50[g]	1.30[g]	.485[g]	0.31[h]		0.42[h]			
Red-tailed Hawk									
1979	4	0	0.353	1.44	0.17	0.20			
1980	?	2	0.477	1.34	0.14	0.15			
1978[b]	3	?	0.417	1.22		3.58			
1979	3	2	0.441	0.87	0.22	0.24	0.43		
1978[b]	?	2	0.407	0.14		0.32			
1979	3	2	0.424						
				0.420[g]	0.49[h]		0.27[h]		
Northern Harrier									
1979	6	0[i]	0.315	1.90	0.18	3.61	0.22		
1978[b]	?	0[i]	0.317	1.06		5.24			
1978	?	0[i]		0.55	0.14	4.15	0.13		
1979	?	0[i]	0.289	0.25		0.61			
			0.307[g]	0.73[h]		2.63[h]			
Prairie Falcon									
1979	5	3	0.372	4.75	0.33	0.86		0.21	0.22
1978[b]	4	?	0.319	1.84		1.11			
			0.346[g]	2.96[h]		0.98[h]			

Note: HE = heptachlor epoxide, OXY = oxychlordane, HCB = hexachlorobenzene, and TRNO = *trans*-nonachlor.
[a]Before sample egg removed. [b]Analyzed at Denver Wildlife Research Center. [c]Also, 0.36 or 0.66 ppm toxaphene. [d]Also, 0.13 ppm DDD. [e]Also, 1.0 ppm PCB's. [f]Recycled after first nest abandoned. [g]Arithmetic mean. [h]Geometric mean. [i]Nests destroyed by farm mowing operations.

less frequently in eggs of the 5 species of owls (Table 2) than in hawk eggs: Western Screech-Owl (5 of 7, 71%), Short-eared Owl (*Asio flammeus*) (3 of 5, 60%), Long-eared Owl (7 of 21, 33%), Burrowing Owl (2 of 6, 33%), and Northern Saw-whet Owl (0 of 4). Our criteria for calculating geometric means (75% of samples with detectable amounts) was not met for HE in any of the owl species. DDE occurred in

eggs at greater frequencies than HE: Western Screech-Owl (6 of 7, 86%), Burrowing Owl (5 of 6, 83%), Long-eared Owl (17 of 21, 81%), Short-eared Owl (4 of 5, 80%), and Northern Saw-whet Owl (1 of 4, 25%). However, the DDE concentrations in owls were low.

Long-eared Owls experienced excellent reproductive success; 16 of 19 nests (84%) were successful. The 3 nests that failed did not contain higher residue concentrations than the successful nests. A test for the logarithmic relationship between DDE and eggshell thickness was not statistically significant ($P > 0.05$). The mean eggshell thickness (0.237±0.003 mm, n =21) was similar to the pre-1947 mean (0.238±0.002 mm, n = 11) from Oregon and Washington.

Western Screech-Owl eggs contained some of the higher DDE residues among the owls (Table 2). Although only 7 Western Screech-Owl eggs were collected, a highly significant logarithmic relationship existed between DDE and eggshell thickness ($Y = 0.211 - 0.025 \log_{10} X$, $r = -0.92$, $P < 0.01$). There was no significant relationship ($P > 0.05$) between HE and eggshell thickness. Mean Western Screech-Owl eggshell thickness of 0.212±0.007 mm was 7.4% thinner ($P < 0.01$) than the pre-1947 mean (0.229±0.004 mm, n = 11) from Oregon and Washington. Laboratory studies showed that 2.8 ppm (wet wt) of DDE in the diet reduced Eastern Screech-Owl (*Otus asio*) eggshell thickness by an average of 12% (McLane and Hall 1972). Residues of DDE in Eastern Screech-Owl eggs from Ohio in

Table 2. Clutch size, fledging success, eggshell thickness, and organochlorine residues (ppm wet wt) in eggs of owls nesting in Umatilla and Morrow counties, Oregon, 1978-81.

Year	Clutch size[a]	Fledged	Shell Thickness (mm)	HE	OXY	DDE	Dieldrin	HCB	PCB's
Long-eared Owl									
1979	5	4	0.237	1.92	0.25	0.14		0.10	
1979	5	3	0.250	0.65	0.11	0.16			
1079	6	5	0.236	0.61		0.45		1.49	
1979	6	5	0.242	0.49		0.15			
1980	5	?	0.243	0.45	0.19	1.04		0.22	
1980	5	4	0.240	0.15		0.16		0.39	
1978	5	0	0.265	0.14					
1980	5	4	0.218			3.32			
1979	7	5	0.221			1.58			
1979	8	0	0.228			0.90			
1980	5	3	0.250			0.56		0.18	
1980	6	4	0.218			0.44			
1978[b]	7	2+	0.247			0.42			0.78
1980	5	?	0.236			0.26		0.48	
1980	6	0	0.234			0.25			
1979	6	5	0.208			0.16			
1980	4	3	0.264			0.12			
1980	7	6	0.254			0.10			
1980	5	4	0.231						
1980	5	4	0.231						
1980	5	4	0.218						
	5.62[c]	3.42[c]	0.237[c]			0.24[d]			

(Table 2 Continued)

(Table 2 Concluded)

Year	Clutch size[a]	Fledged	Shell Thickness (mm)	HE	OXY	DDE	Dieldrin	HCB	PCB's
Western Screech-Owl									
1979	5	4	0.225	3.15	0.39	0.55		0.39	2.76
1979	1[e]	X	0.189	2.57	0.73	3.94	0.15	0.11	1.01
1980	4	0	0.204	1.03	0.13	0.60			
1978[b]	?	2	0.206	0.46		1.98			
1979[f]	3	0	0.201	0.30	0.28	3.43	0.50	0.10	
1980	5	4	0.215			1.06			
1981	4	3	0.243						
	4.20[c]	2.17[c]	0.212[c]			0.90[d]			
Burrowing Owl									
1981	6	0	0.178	0.19		0.66			
1981	5	0[g]	0.182	0.16		0.24			
1979	10	7	0.172			0.18			
1980	8	7	0.174			0.14			
1980	10	?	0.180			0.11			
1980	12	10	0.192						
	8.50[c]		0.180[c]			0.17[d]			
Short-eared Owl									
1979	6+	3	0.246	1.70	0.33	0.20		0.51	
1980	4	?	0.277	0.99	0.35	0.29	0.24		
1978[b]	?	0[h]	0.216	0.61		1.08			
1979	8	5+	0.235			0.74		0.26	
1979	9	3+	0.258				0.85		
			0.246[c]			0.30[d]			
Northern Saw-whet Owl									
1978	5+	3	0.185			0.11			
1979	6	5	0.197						
1981	7	3	0.192						
1981	6	2	0.191						
			0.191[c]						

Note: HE= heptachlor epoxide, OXY = oxychlordane, HCB = hexachlorobenzene, PCB's = polychlorinated biphenyls.
[a]Before sample egg removed. [b]Analyzed at Denver Wildlife Research Center. [c]Arithmetic mean. [d]Geometric mean. [e]Lone egg found in nest box. [f]Also, 0.96 ppm *cis*-chlordane. [g]Four hatched but depredated by a Badger (*Taxidea taxus*). [h]Nest destroyed by farm mowing operation.

1973 were generally low (arithmetic $\bar{x}$ 1.29 ppm wet wt, range 0.33-2.8) and no relationship was found between hatching failure and presence of organochlorine residues (Klaas and Swineford 1976). For comparison, the arithmetic mean for DDE in this study was 1.65 ppm.

The shell thickness of 6 Burrowing Owl eggs averaged 0.180±0.003 mm which was not significantly different from 6 eggs collected in Oregon and Washington before 1947 (0.191±0.009 mm). Short-eared Owl eggs showed a mean shell thickness of 0.246±0.010 mm which was nearly identical to the 0.245±0.006 mm from 3 eggs collected in Oregon and Washington prior to 1947. Northern Saw-whet Owl eggs had a mean shell thickness of 0.191±0.003 mm; however, no historical eggs were available from the region for comparison. DDE residues were generally < 1 ppm in eggs of these 3 species of owls.

Eagles and Hawks Found Dead. — Although eggs from Golden Eagle nests in the region were not collected, 8 eagles found dead were analyzed (Table 3). Residues of HE in brain tissue of 3 Golden Eagles (7.9, 10, and 13 ppm) were diagnostic of HE poisoning (i.e., > 8 ppm established for experimental birds [Stickel et al. 1979]). The eagle with 4.7 ppm HE died under suspicious circumstances; it was observed gliding and then fatally diving straight into the ground! Rough-legged Hawks nest in the Arctic and winter in the region, but 1 bird accumulated lethal residues of HE. A nesting American Kestrel died in its nest box with 28 ppm HE in her brain; an egg she laid contained the highest HE concentration among the 261 kestrel eggs collected during a 4-year study (Henny et al. 1983). The birds with lethal HE residues died in March, April, May, and June which is considerably after the fall planting time for heptachlor-treated wheat seeds.

ACKNOWLEDGMENTS

Biological technicians collecting field data for this study included E.G. Huff, R.R. Sheehy, G.A. Green, B.E. Forman, K.D. Hansen, and R.A. Grove. J.E. Kurtz and G.M. Constantino, refuge managers at Umatilla NWR, kindly allowed use of refuge facilities as our field operations center. S.A. Rohwer, Thomas Burke Memorial Museum, Seattle; G.D. Alcorn, University of Puget Sound Museum, Tacoma; and the staff of the University of Oregon Museum, Eugene, assisted in obtaining measurements from pre-DDT era eggs housed at their facilities. E.F. Hill and D.H. White of the Patuxent Wildlife Research Center and G.A. Fox of the Canadian Wildlife Service improved the manuscript with their thoughtful reviews. We thank all who assisted in this effort.

ADDENDA

A Barn Owl (*Tyto alba*) found dead in the study area on 1 January 1984 had the following residues (ppm wet wt) in its

Table 3. Organochlorine residues (ppm wet wt) in brain tissue of eagles and hawks found dead in Umatilla and Morrow counties, Oregon, 1977-80.

Species	Wt (g)	Age	Sex	Date	HE	OXY	DDE	Dieldrin	TRNO	HCB	PCB's
Golden Eagle[a]	2640	Adult	M	30 April 1977	10	0.62	1.1	0.75	0.40	0.29	0.61
Golden Eagle[b]	3600	Adult	M	May-June 1978	13	0.69	0.49		0.43	0.21	
Golden Eagle	4825	Adult	F	Winter 78-79							
Golden Eagle	4500	S Ad	F	Winter 78-79			0.11				
Golden Eagle	3350	S Ad	M	Winter 78-79	0.10						
Golden Eagle	3225	Adult	M	Early 1979	1.5	0.12					
Golden Eagle	4025	Adult	F	3 May 1980	4.7	0.30	1.8		0.12		0.89
Golden Eagle	2900	S Ad	M	17 June 1980	7.9	0.67	1.5	0.26	0.31		1.6
Red-tailed Hawk	1050	Juv	M	10 Feb 1980							
Rough-legged Hawk	728	Juv	F	20 March 1980	20	2.4	0.42		0.34	7.4	
American Kestrel[c]		Adult	F	11 June 1979	28	2.5	0.35		0.95	0.21	

Note: SAd = subadult (has white on tail or wings; see Steenhof et al. 1983), Juv (in second calendar year of life; juvenal plumage); HE = heptachlor epoxide, OXY = oxychlordane, TRNO = *trans*-nonachlor, HCB = hexachlorobenzene, PCB's = polychlorinated biphenyls.

[a]Fell from sky, hit ground and began convulsing. [b]Found alive; no coordination and some muscle twitching. [c]See Henny et al. (1983) for details.

brain: heptachlor epoxide 1.1, oxychlordane 0.31, *trans*-nonachlor 0.10, and DDE 0.18. Thus, another raptor species in the area accumulated residues of heptachlor epoxide.

LITERATURE CITED

ANDERSON, D.W. AND J.J. HICKEY. 1972. Eggshell changes in certain North American birds. *Proc. Internatl. Ornithol. Cong.* 15:514-540.

ANON. (various dates). Pacific Northwest Insect Control Handbook. Compiled and edited annually by Extension Entomologists of Oregon State Univ., Washington State Univ., and Univ. of Idaho. Oregon State Univ. Book Stores, Inc., Corvallis.

BECHARD, M. 1981. DDT and hexachlorobenzene residues in southeastern Washington Swainson's Hawks (*Buteo swainsoni*). *Bull. Environ. Contam. Toxicol.* 26:248-253.

BLUS, L.J., C.J. HENNY, D.J. LENHART AND E. CROMARTIE. 1979. Effects of heptachlor-treated cereal grains on Canada Geese in the Columbia Basin. *In:* Management and Biology of Pacific Flyway Geese: A Symposium. R.L. Jarvis and J.C. Bartonek (eds.). Oregon State Univ. Book Stores, Inc., Corvallis. pp. 105-116.

CROMARTIE, E., W.L. REICHEL, L.N. LOCKE, A.A. BELISLE, T.E. KAISER, T.G. LAMONT, B.M. MULHERN, R.M. PROUTY AND D.M. SWINEFORD. 1975. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for Bald Eagles, 1971-72. *Pestic. Monit. J.* 9:11-14.

FISHER, A.K. 1893. The Hawks and Owls of the United States in Their Relation to Agriculture. U.S. Dept. Agric., Div. Ornithol. Mammal. Bull. 3.

HENNY, C.J. AND L.J. BLUS. 1981. Artificial burrows provide new insight into Burrowing Owl nesting biology. *Raptor Res.* 15:82-85.

HENNY, C.J. AND T.E. KAISER. 1979. Organochlorine and mercury residues in Swainson's Hawk eggs from the Pacific Northwest. *Murrelet* 60:2-5.

HENNY, C.J., L.J. BLUS AND C.J. STAFFORD. 1983. Effects of heptachlor on American Kestrels in the Columbia Basin, Oregon. *J. Wildl. Manage.* 47:1080-1087.

KAISER, T.E., W.L. REICHEL, L.N. LOCKE, E. CROMARTIE, A.J. KRYNITSKY, T.G. LAMONT, B.M. MULHERN, R.M. PROUTY, C.J. STAFFORD AND D.M. SWINEFORD. 1980. Organochlorine pesticide, PCB and PBB residues and necropsy data for Bald Eagles from 29 states — 1975-77. *Pestic. Monit. J.* 13:145-149.

KLAAS, E.E. AND D.M. SWINEFORD. 1976. Chemical content and hatchability of Screech Owl eggs. *Wilson Bull.* 88:421-426.

LINCER, J.L. 1975. DDE-induced eggshell thinning in the American Kestrel: A comparison of the field situation with laboratory results. *J. Appl. Ecol.* 12:781-793.

MCLANE, M.A. R. AND L.C. HALL. 1972. DDE thins Screech Owl eggshells. *Bull. Environ. Contam. Toxicol.* 8:65-68.

PETERSON, J.E., K.M. STAHL AND D.L. MEEKER. 1976. Simplified extraction and cleanup for determining organochlorine pesticides in small biological samples. *Bull. Environ. Contam. Toxicol.* 15:135-139.

STEENHOF, K., M.N. KOCHERT, AND J.H. DOREMUS. 1983. Nesting of subadult Golden Eagles in southwestern Idaho. *Auk* 100:743-747.

STICKEL, L.F., S.N. WIEMEYER AND L.J. BLUS. 1973. Pesticide residues in eggs of wild birds: Adjustment for loss of moisture and lipid. *Bull. Environ. Contam. Toxicol.* 9:193-196.

STICKEL, L.F., W.H. STICKEL, R.D. MCARTHUR AND D.L. HUGHES. 1979. Chlordane in birds: A study of lethal residues and loss rates. *In* Toxicology and Occupational Medicine. W.B. Deichmann (organizer). Elsevier/North Holland, New York. pp. 387-396.

THUROW, T.L., C.M. WHITE, R.P. HOWARD, AND J.F. SULLIVAN. 1980. Raptor ecology of Raft River Valley, Idaho. U.S. Dept. Energy, Idaho National Engineering Laboratory, EGG-2054, Idaho Falls, Idaho. 45 pp.

U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, 480 SW Airport Road, Corvallis, OR 97333. Address of third author: U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD 20708

Received 10 March 1984; Accepted 9 May 1984.

BREEDING ECOLOGY OF BARRED OWLS IN THE CENTRAL APPALACHIANS

JAMES G. DEVEREUX AND JAMES A. MOSHER

ABSTRACT - Eight pairs of breeding Barred Owls (*Strix varia*) in western Maryland were studied. Nest site habitat was sampled and quantified using a modification of the James and Shugart (1970) technique (see Titus and Mosher 1981). Statistical comparison to 76 random habitat plots showed nest sites were in more mature forest stands and closer to forest openings. There was no apparent association of nest sites with water. Cavity dimensions were compared statistically with 41 randomly selected cavities. Except for cavity height, there were no statistically significant differences between them.

Small mammals comprised 65.9% of the total number of prey items recorded, of which 81.5% were members of the families Cricetidae and Soricidae. Birds accounted for 14.6% of the prey items and crayfish and insects 19.5%. We also recorded an apparent instance of juvenile cannibalism.

Thirteen nestlings were produced in 7 nests, averaging 1.9 young per nest. Only 2 of 5 nests, where the outcome was known, fledged young.

The Barred Owl (*Strix varia*) is a common nocturnal raptor in forests of the eastern United States, though few detailed studies of it have been published. Most reports are of single nesting occurrences and general observations (Bolles 1890; Carter 1925; Henderson 1933; Robertson 1959; Brown 1962; Caldwell 1972; Hamerstrom 1973; Appelgate 1975; Soucy 1976; Bird and Wright 1977; Leder and Walters 1980). Habitat was described qualitatively by Nicholls and Warner (1972) and Fuller (1979). Barred Owl food habits were reported by Cahn and Kemp (1930), Errington (1932), Errington and McDonald (1937), Wilson (1938), Mendall (1944), Hamerstrom and Hamerstrom (1951), Blakemore (1960) LeDuc (1970), and Korschgen and Stuart (1972). The food habits studied, however, were all from midwestern states, except Mendall's (1944) study from Maine. Dunstan and Sample (1972) reported the number of fledglings from 1 cavity each year for 5 years, but provided no other productivity information. Clutch sizes in various geographic regions can be found in Bent (1961) and Murray (1976).

This study was conducted in an area where 4 diurnal raptor species, the Red-shouldered Hawk (*Buteo lineatus*), Broad-winged Hawk (*B. platypterus*), Red-tailed Hawk (*B. jamaicensis*) and Cooper's Hawk (*Accipiter cooperi*), were also under study (see Titus and Mosher 1981, Janik and Mosher 1982). Our objectives were to quantitatively describe vegetation structure at Barred Owl nest sites and compare it with surrounding habitat, measure and compare dimensions of cavities used by them with those from randomly selected cavities, describe their food habits for this geographic region, and determine their breeding chronology and productivity.

STUDY AREA AND METHODS

The study was conducted in Green Ridge State Forest (GRSF), Allegany County, Maryland. It is within the Ridge and Valley physiographic region (Stone and Matthews 1977), characterized by narrow mountain ridges oriented northeast to southwest separated by steep narrow valleys (see Titus 1980).

About 74% of the county and nearly all of GRSF is forested Major forest types were described by Brush et al. (1980). Predominant tree species include white oak (*Quercus alba*), red oak (*Q. rubra*), chestnut oak (*Q. prinus*), scarlet oak (*Q. coccinea*), red maple (*Acer rubrum*), and pignut and mockernut hickories (*Carya glabra* and *C. tomentosa*). Predominant understory species include flowering dogwood (*Cornus florida*), sassafras (*Sassafras albidum*), serviceberry (*Amelanchier* spp.), and saplings of the dominant trees.

The study area was systematically searched for active nests from late February through May in 1981 and 1982. During 1982, tape recorded Barred Owl calls were broadcast in order to elicit responses and help localize nesting pairs.

Nest sites were plotted on 7.5 min USGS topographic maps and County Soil Conservation Service maps. A nest site was defined as a 0.4 ha plot (11.3 m radius) centered on the nest tree. This size plot was considered more time and field efficient than either smaller or larger size plots when making quantitative estimates of the vegetation (Lindsey et al. 1958, James and Shugart 1970).

Nests were checked periodically each season to obtain nesting chronology and productivity information. At the same time, regurgitated pellets found in the cavities were collected and any prey remains were noted.

At the end of the nesting season, vegetation at each active nest site was sampled using a modificaton of the James and Shugart technique (1970), as described by Titus and Mosher (1981). Thirty-four variables were measured or derived at each site (Table 1). The type of cavity in which a pair nested (hollow tree stub, hole from disease, excavated hole, or hole from broken limb) and successional stage of the cavity tree (Fig. 1) were recorded.

Height to cavity entrance was measured with a meter tape for trees climbed, otherwise height measurements and percent slope were measured with a Haga altimeter. Percent canopy, understory and ground covers were based on 40 ocular tube readings, 10 along each of 4 transects starting at the nest tree and extending in each of the cardinal compass directions.

We compared nest site data with random habitat samples collected by Titus and Mosher (1981) to determine if vegetation structure around nest trees differed from surrounding habitat. Variables measured at random plots are listed in Table 1 except

Table 1. Quantative habitat variables and cavity characteristics used in analysis of Barred Owl nest site habitat

1. ALTITUDE	Altitude of plot in meters; taken from U.S.G.S. 7.5-min. quadrangles
2. SOIL	Soil-woods suitability; measures suitability for tree productivity; class 1 indicates high productivity and class 6 indicates low productivity (Stone and Matthews 1977)
3. SITINDX	Site index; based on SOIL and the tree species present in the plot (Stone and Matthews 1977)
4. WATER	Distance to water in meters
5. DISFOROP	Distance to the nearest forest opening in meters; measured to the nearest break in forest continuity, such as created by trail, road, field, etc.
6. PERSLOP	Percent slope of plot
7. CANHT	Canopy height of the plot in meters; the mean of 5 measurements taken to the top of the canopy
8. CANEVER	Percentage evergreen canopy cover
9. CANTOT	Percentage total canopy cover
10. UNDEVER	Percentage evergreen understory cover
11. UNDTOT	Percentage total understory cover
12. GRNDEVER	Percentage evergreen ground cover
13. GRNDTOT	Percentage total ground cover
14. SHRUBDEN	Shrub density (James and Shugart 1970, James 1978)
15. SHRUBIND	Shrub index (Titus 1980)
16. NOSPTREE	Number of species of overstory trees in the plot
17. NOSPSHRB	Number of species of shrubs and saplings in the plot
18. NOTREES	Number of overstory trees in the plot
19. UND14	Number of understory stems 1-4 cm diameter in the plot
20. UND58	Number of understory stems 5-8 cm diameter in the plot
21. UNDGT8	Number of understory stems greater than 8 cm diameter in the plot
22. DBHLT26	Number of overstory trees less than 26 cm dbh in the plot
23. DBH2650	Number of overstory trees 26-50 cm dbh in the plot
24. DBHGT50	Number of overstory trees greater than 50 cm dbh in the plot
25. BASAL	Basal area in m^2/ha for overstory trees
26. DBH*	Diameter at breast height of nest tree
27. TREEHT*	Height of cavity tree in meters
28. CAVHT*	Height to lowest point of cavity entrance in meters
29. %CAVHT*	Percentage cavity height; calculated as: (CAVHT/CANHT) (100) = %CAVHT
30. TREEDIAM*	Diameter of cavity tree at cavity height
31. HORIZONT*	Horizontal length of cavity opening in cm
32. VERTICAL*	Vertical length of cavity opening in cm

(Table 1 continued)

(Table 1 concluded)

33.	CAVDIAM*	Inside diameter of cavity in cm; measured from inside of entrance to back wall; for hollow tree stubs, the largest diameter is recorded
34.	CAVDEPTH*	Cavity depth in cm; measured from lowest point of cavity entrance to base of cavity.

(* = variables unique to cavities and cavity trees).

for the cavity and cavity tree specific variables.

Dimensions of 41 randomly selected, unoccupied cavities were measured and compared with nest cavities to provide a measure of cavity sizes availble to Barred Owls and assess cavity selection. The random sampling of cavities was stratified. Transects, approximately 100 m apart, 1.6 km long extending on both sides of a road running the length of the study area, were randomly chosen. A coin flip determined which side of the road the transect was walked. Every third cavity encountered was measured but no more than 3/transect to avoid measuring too many within a single habitat type. The criteria for accepting a random cavity was that it be at least 2 m from the ground and have at least a 15 cm diameter opening, or, for a hollow tree stub, a 25 cm dbh.

Minimum sample sizes were calculated for each variable to determine if random sampling was adequate. Sample sizes were considered adequate if they met the criteria of remaining within 20% of the mean for 95% of the samples. Twenty of 25 variables pertaining to habitat structure met this criteria with < 76 samples. Seven of 9 cavity and cavity tree variables met this criteria with sample sizes of < 41.

Habitat data were subjected to nonparametric statistical analyses conducted on the Statistical Package for the Social Sciences (SPSS) computer program (Nie et al. 1975, Hull and Nie 1981). Two sets of Kruskall-Wallis one-way analysis of variance (Siegal 1956) tested for similarity between nest site habitat and random habitat plots, and nest site cavity and random cavity dimensions. Spearman rank correlation coefficients (Siegal 1956) were calculated to determine the extent of correlation among structural features of habitat and among cavity characteristics X^2 goodness-of-fit tests were used on pooled samples of nest site and random cavities to determine if differences existed among the number of each cavity type found and number of cavity trees in each successional stage. Test results were considered significant if $P < 0.05$.

RESULTS AND DISCUSSION

Habitat. — Eight-Barred Owl nests were located. The 4 found in 1981 were not reused in 1982. Nest site habitat and random habitat plots were significantly different between groups for 7 of 25 variables (Table 2). Nest sites were found significantly closer to forest openings than random sites, in habitats with well developed understories. Percent understory cover and the number of stems greater than 8 cm diameter, both positively correlated with each

Table 2. Means ± standard deviations and ranges of habitat variables at Barred Owl nest sites and random habitat plots, and results from Kruskal-Wallis one-way ANOVA (chi-square statistic) testing for significant differences between groups.

Habitat variable[a]	Barred owl nest sites (N = 8)	Random sites (N = 76)	Kruskal-Wallis X^2 value
ALTITUDE	1239 ± 517 (820 – 2420)	1356 ± 613 (560 – 2860)	0.084
SOIL	3.6 ± 1.4 (1 – 6)	3.9 ± 1.3 (1 – 6)	0.093
SITINDX	65 ± 11.7 (45 – 85)	61.4 ± 12.5 (40 – 90)	0.410
WATER	218 ± 222 (15 – 675	320 ± 243 (35 – 1050)	1.860

(Table 2 continued)

(Continuation of Table 2)

Habitat variable[a]	Barred owl nest sites (N = 8)	Random sites (N = 76)	Kruskal-Wallis X^2 value
DISFOROP	85 ± 116 (4 – 350)	221 ± 209 (8 – 1110)	7.481**
PERSLOP	9.4 ± 12.9 (0 – 40)	21.6 ± 13.3 (3 – 80)	0.107
CANHT	23.5 ± 3.3 (19 – 28)	20.6 ± 4.5 (10 – 31)	2.991
CANEVER	7 ± 13 (0 – 32)	6 ± 14 (0 – 53)	0.019
CANTOT	68 ± 21 (30 – 98)	75 ± 9 (43 – 90)	0.230
UNDEVER	0	2 ± 7 (0 – 37)	0.535
UNDTOT	67 ± 14 (50 – 90	53 ± 14 (17 – 80)	5.120*
GRNDEVER	0	.5 ± 3 (0 – 30)	0.059
GRNDTOT	43 ± 13 (23 – 68)	38 ± 16 (10 – 75)	0.893
SHRUBDEN	23 ± 19 (5 – 68)	24 ± 11 (3 – 64)	1.074
SHRUBIND	42 ± 23 (10 – 83)	50 ± 21 (14 – 115)	1.220
NOSPTREE	4.5 ± 1.7 (3 – 7)	4.6 ± 1.8 (1 – 10)	0.046
NOSPSHRB	11.4 ± 2.8 (8 – 16)	10.1 ± 2.9 (5 – 17)	1.395
NOTREES	10.9 ± 3.6 (4 – 17)	19.5 ± 10) (7 – 48)	7.315**
UND14	69.8 ± 34.9 (28 – 131)	74.3 ± 33.3 (9 – 154)	0.245
UND58	17.5 ± 8.8 (3 – 33)	12.7 ± 8.7 (1 – 45)	2.874

(Table 2 continued)

(Table 2 concluded)

Habitat variable[a]	Barred owl nest sites (N = 8)	Random sites (N = 76)	Kruskal-Wallis X^2 value
UNDGT8	9.5 ± 3.7 (4 – 16)	5.9 ± 3.6 (0 – 14)	5.870*
DBHLT26	5.1 ± 3.2 (0 – 10)	14.7 ± 11.6 (0 – 48)	6.554**
DBH2650	3.9 ± 2.2 (2 – 8)	4.6 ± 2.8 (0 – 12)	0.665
DBHGT50	1.8 ± 1.2 (0 – 4)	0.2 ± 0.6 (0 – 3)	12.714***
BASAL	28.4 ± 5.8 (21.7 * 40.1)	20 ± 5.5 (3.9 – 34.2)	11.755***

[a]Mnemonic names defined in Table 1.
(* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$).

other ($r = 0.24$, $P = 0.03$, $N = 84$), were significantly higher at nest sites. There were fewer overstory trees, because of fewer trees in the < 26 cm dbh size class. There were significantly more trees > 50 cm dbh at nest sites (45/ha vs 5/ha at random sites), and greater basal area.

These results are in general agreement with the qualitative habitat descriptions provided by previous authors (i.e., Barred Owls utilize forest stands mature enough to provide suitable nesting cavities). Craighead and Craighead (1969) suggested one of the reasons Barred Owls were absent from part of their study area was a lack of mature basswoods (*Tilia* sp.) and a lack of heart rot fungus in woodlots that had mature trees. However, owls are known to nest in old hawk or squirrel nests, as did 1 pair in this study, and 23 of 38 pairs reported by Bent (1938). Bent suggested that they choose alternative nests because of lack of cavities. Hilden (1965) and Temple (1977) indicated that birds may shift from their traditional nesting sites by imprinting on the type of nests from which they fledge. If this occurs in Barred Owls, those raised in old hawk or squirrel nests may subsequently use these nest types regardless of cavity availability.

Much literature on Barred Owls indicates an apparent association with wet areas (Carter 1925, Errington and McDonald 1937, Bent 1938, Appelgate 1975, Soucy 1976), perhaps because such areas are often inacessible or too wet to be logged, thereby providing old growth timber and abundant nesting cavities. We found no difference in the proximity to water between nest sites and random habitat plots. The average distance to water was 218 m with only 1 nest located on a stream "floodplain". Furthermore, Nicholls and Warner (1972) and Fuller (1979), both radiotelemetry studies, reported that Barred Owls utilized oak-upland habitat more frequently and consistently than any other habitat type including white cedar (*Thuja occidentalis*) swamps, alder (*Alnus* spp.) swamps, and marshes. Nicholls and Warner (1972) suggested that owls used upland sites because of more suitable nest sites, abundance of hunting perches, open understory for hunting, and the opportunity to hear prey better in dry areas.

Bent (1938) reported that distribution of Barred Owls in southern New England coincides with Red-shouldered Hawks and noted they are often found in the same woodlot. In this study, forest structure around Barred Owl nest sites was similar to that of sympatric Red-shouldered Hawks, both species utilizing old growth timber for nesting. Six of the 7 significant variables listed in Table 2 were also significant for the Red-shouldered Hawk (Titus and Mosher 1981). Apparent differences

between them were that Red-shouldered Hawk nests were no closer to forest openings than random habitat plots, but were significantly closer to water, and there was a higher shrub density at Red-shoulder occupied sites.

Cavities. — Six Barred Owl nests were in the top of hollow tree stubs, 1 in a cavity created by disease and 1 in an old stick nest. The high incidence of hollow tree stubs as nest sites is probably a reflection of cavity type availability in this area. Sixty-nine percent of the total number of cavities measured were hollow tree stubs, significantly more than the other 3 types (X^2 = 54.17, 3 df, $P < 0.05$). Twenty-three percent were holes,resulting from broken limbs and 8% were holes created by disease. No excavated holes were found that met the criteria to be included in the random cavity sample. Four of the 7 nesting cavities were in trees in the second successional stage (see Fig. 1) and 1 each in the third, fourth and fifth stages. There was no statistical difference in the total number of cavity trees in each of the 5 successional tree stages (X^2 = 9.29, 4 df, $P < 0.05$).

There was a significant difference between ran-

Table 3. Means ± standard deviation and ranges of cavity and cavity tree dimensions for Barred Owl nest site cavities and random cavities, and results from Kruskal-Wallis one-way Anova (chi-square statistics) testing for similarity between groups.

Cavity variable[a]	Nest site cavities	N	Random cavities	N	Kruskal-Wallis X^2square value
DBH	61 ± 15 (42 – 88)	7	53 ± 13 (26 – 90)	41	1.652
TREEHT	15.4 ± 5.8 (10 – 25)	7	12.9 ± 7.1 (3 – 24)	41	1.137
CAVHT	9.1 ± 2.9 (4 – 14)	7	6.3 ± 3.1 (2 – 17)	41	5.5999*
%CAVHT	39 ± 11 (17 – 50)	7	30 ± 14 (10 – 71)	41	2.724
TREEDIAM	46 ± 8 (36 – 54)	4	48 ± 11 (25 – 69)	33	0.048
HORIZONT	15 ± 0	1	21 ± 8 (12 – 40)	12	2.571
VERTICAL	45 ± 0	1	49 ± 35 (20 – 140)	12	2.571
CAVDIAM	33 ± 8 (22 – 41)	6	30 ± 10 (11 – 60)	33	0.985
CAVDEPTH	54 ± 44 (3 – 130)	6	167 ± 203 (0 – 800)	33	0.767

[a]Mnemonic names defined in Table 1.

(* = $P < 0.05$).

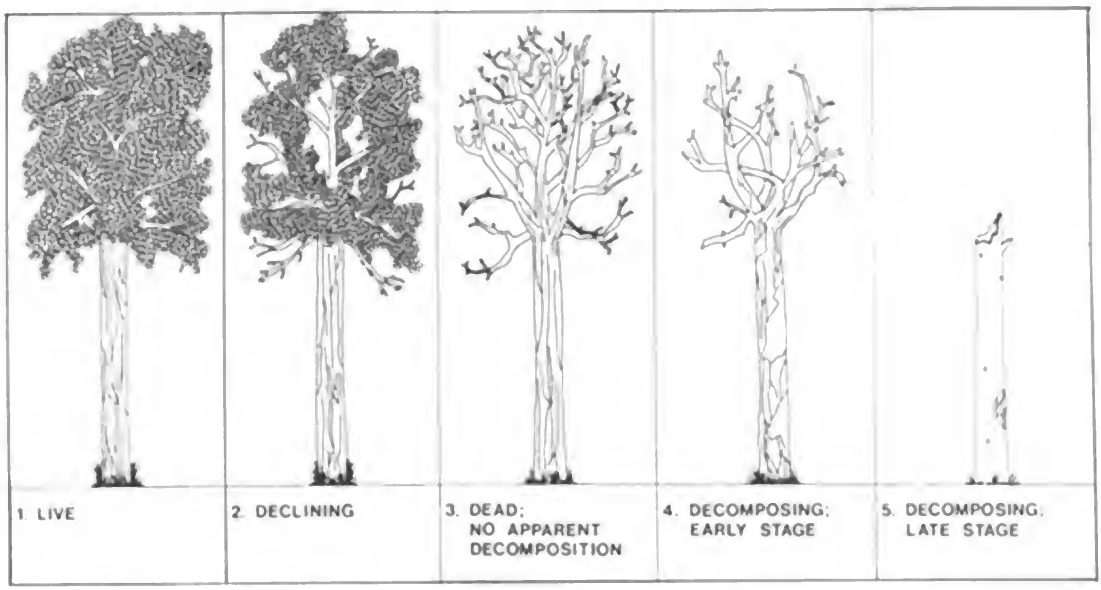

Figure 1. Successional stages for describing Barred Owl cavity trees: 1. LIVE - tree is apparently healthy except for cavity; 2. DECLINING - tree is obviously declining; losing leaves; some dead branches; 3. DEAD; NO APPARENT DECOMPOSITION - no leaves; tree still has all or most of bark; some branches may be broken; no apparent rotting of wood; 4. DECOMPOSING; EARLY STAGE - many broken branches; bark falling off; wood becoming soft in spots; 5. DECOMPOSING; LATE STAGE - little or no bark on tree; very soft wood; broken tree stub is often all that remains

dom and nest site cavity dimensions for only 1 of 9 variables (Table 3). Cavities used by owls averaged 3 m higher than random cavities. Cavity depth of nest site cavities was highly variable, ranging from 3 - 130 cm. Bent (1938) recorded a depth for 1 Barred Owl cavity of 244 cm.

The cavity data suggest that most cavities, given certain minimum dimensions, may be suitable for nesting. Nest trees generally have at least a 25 cm dbh and those with cavities 9 m or more above ground may be preferred. Most reported dimensions (Bent 1938; Allin 1944; LeDuc 1970; Dunstan and Sample 1972; Soucy 1976 Leder and Walters 1980) are less than the maximum cavity dimensions we found. Few data exist on the length and/or width of cavity openings. Hamerstrom (1972) recommended a 20 cm dia opening when constructing a nest box for this species but did not indicate the basis for this measurement. Forsman (1975) reported a range of cavity entrance widths of 15.2 - 55.9 cm for 10 cavities used by the closely related Spotted Owl (*Strix occidentalis*).

Food Habits. — Barred Owl food habits in the GRSF region are summarized in Table 4. The percent occurrence of mammals and birds is fairly typical of what has been reported in the literature. Fish, reptiles, amphibians, and arthropods have also been recorded as prey items but are probably more important to individual owl pairs than to a regional population. The majority of crayfish recorded as prey in this study, for example, were from 2 nests.

Jaksic (1982) hypothesized that temporal segregations of falconiform and strigiform raptors may not reduce competition for food between groups. However, his data for Barred Owls revealed little dietary overlap with falconiform species, except with the American Kestrel (*Falco sparverius*). We also observed little overlap. Sciuridae mammals were clearly the major prey for the 4 hawk species on the study area (Janik and Mosher 1982), while Cricetidae and Soricidae species, which accounted for 81.5% of the mammals and 53.7% of the total number of prey items, were the predominant prey for owls. Furthermore, Flying Squirrels and Crayfish, both nocturnal and not recorded as prey items for the hawks, comprised 8.5% and 12.2% of the total number of prey items recorded, respectively.

Table 4. Food habits of Barred Owls in the Central Appalachians[a].

Prey Species	Occurrence	%
Mammals		
Southern Flying Squirrel (*Glaucomys volansi*)	7	
Shorttail Shrew (*Blarina brevicauda*)	7	
Peromyscus spp.	5	
Meadow Vole (*Microtus pennsylvanicus*)	4	
Eastern Chipmunk (*Tamias striatus*)	2	
Red Squirrel (*Tamiasciurus hudsonicus*)	1	
Unidentified *Cricetidae* sp.	16	
Unidentified *Soricidae* sp.	12	
Total	54	65.9
Birds		
Scarlet Tanager (*Piranga olivacea*)	3	
Eastern Phoebe (*Sayornis phoebe*)	2	
Blue Jay (*Cyanocitta cristata*)	1	
Unidentified	6	
Total	12	14.6
Arthropods		
Crayfish (*Cambarus* sp.)	10	
Unidentified insects	6	
Total	16	19.5
Total Items	82	100.0

[a]Based on prey remains and analysis of pellets from seven nests.

One nestling, about 28 d old, was cannabilized by its sibling. Most of its body was eaten; legs, and skin and feathers of the back were all that remained. Based on growth measurements being taken every 3 to 4 d, both nestlings appeared healthy and were of relatively equal size at 27 d old. The cause of death was unknown but fratricide in raptors usually occurs shortly after the second young hatches (Stinson 1979) and among nestlings of considerable size difference (Ingram 1959), neither of which were the case in this incident. Juvenile cannibalism is not an uncommon occurrence among raptors, but to our knowledge has not previously been documented for Barred Owls.

Nesting Chronology and Productivity. — Nesting chronology and productivity parameters are summarized in Table 5. Hatch dates were fairly consistent among nests, 5 out of 6 hatching within 7 d of each other. Mean egg dates indicate Barred Owls begin nesting about 1 wk before Red-tails (Janik 1980), the earliest nester of the hawk species for this area.

Average clutch size/nest was 2.3, slightly higher than the 2.0 reported by Murray (1976) for Barred Owls in this region and latitude. A total of 13 nestlings were produced in 7 nests, averaging 1.9 young/active nest. The outcome of 5 nests was known. Of these, only 2 fledged young. The eggs rolled out of 1 nest and the nestlings in the other 2 were preyed upon, perhaps as a result of human activity at the nest sites.

The 2 young in successful nests emerged from their cavities when 31 ± 1 d and 30 ± 1 d old, respectively. At this age, Barred Owls are essentially flightless. Primary remiges and rectrices of these 2 owls were only 50 and 12% of adult size, respectively, within 2 d of fledging. Bent (1938) also reported nestling Barred Owls climbing out of their cavities

Table 5. Nesting chronology and productivity of Barred Owls in the central Appalachians, 1981-1982 (# of nests in parentheses).

Mean egg date[a] (6)	20 March
Mean hatch date (6)	10 April
Mean nest departure date (2)	24 May
Mean clutch size (7)	2.3
Total eggs producted[b] (8)	19.0
% hatching success (8)	68.4
# of nestlings per active nest (7)	1.9
Total number fledged (5)	2.0
# fledged/successful nest attempt (2)	1.0
% nesting attempts successful (2/5)	40.0

[a]Egg dates based on back dating from hatch dates using a 28-day incubation period (Bent 1938)

[b]Minimal number of eggs produced based on # of hatchlings and/or eggs found in nests

at 28-35 d old. Forsman (1975) reported Spotted Owls leaving their cavities at 34-36 d old. Dunstan and Sample (1972) and Soucy (1976), however, reported Barred Owls not leaving nests until about 49 d old. The age at which owls emerge may be a factor of cavity size. Those in small, cramped cavities, unable to spread and exercise their wings, may emerge at an earlier age.

Leaving the nest early is a disadvantage from a development standpoint because additional energy is required to compensate for that lost to environmental stress and increased activity. This was suggested by measurements of 1 of the owls that weighed the same 2 d after leaving the nest as 2 d before leaving. However, mobility vs sitting in the nest may be advantageous in terms of predator avoidance. Birds in cavities are especially vulnerable to predation because there is usually only 1 escape route. Young Barred Owls that do leave nests at a preflight stage are not totally helpless. Adult Barred Owls will continue to feed and defend their young throughout the summer, even after they can fly (Henderson 1933, Bent 1938, Dunstan and Sample 1975, Bird and Wright 1977). Also, young Barred Owls have the ability to climb trees using their beaks and talons (Dunstan and Sample 1972). Thus, they are able to move about, first by gliding or fluttering to the ground, then climbing a nearby tree. Tree climbing has also been reported for Great-horned Owl (*Bubo virginianus*), Screech Owl (*Otus asio*) (Dunstan and Sample 1972) and Spotted Owl (Forsman 1975).

CONCLUSIONS

Secondary cavity nesting birds, including the Barred Owl, cannot choose a location within a habitat to "place" their nests. They are limited to what is already available. The data indicate that differences exist between Barred Owl nest site habitat and surrounding habitat, but do not indicate whether cavities are selected based on those differences. Further study is needed to answer this question.

ACKNOWLEDGEMENTS

We thank J. Coleman, L. Garrett, M. Kopeny, D. Lyons, F. Presley, R. Whetstone and K. Titus for their time and assistance We also thank S. Postupalsky for comments on an earlier version of the manuscript. This study was supported, in part, by grants from Sigma Xi, the Maryland Ornithological Society, and the U.S Fish and Wildlife Service (FWS 14-16-0009-80-007). This is Scientific Series No. 1549-AEL of the Appalachian Environmental Laboratory and Technical Report-10 of the Central Appalachian Raptor Ecology Program.

LITERATURE CITED

ALLIN, A.E. 1944. Nesting of the barred owl (*Strix varia*) in Ontario. *Can. Field Nat.* 58:8-9.

APPELGATE, R.D. 1975. Co-roosting of barred owls and common grackles. *Bird Banding* 42:169-170.

BENT, A.C. 1938. Life histories of North American birds of prey. Part II. U.S. Natl. Mus. Bull. 170. Washington, D.C. 482 pp.

BIRD, D.M, AND J. WRIGHT. 1977. Apparent distraction display by a barred owl. *Can. Field Nat.* 91:176-177.

BLAKEMORE, L.A. 1960. Barred owl food habits in Glenwood Park, Minneapolis, Minnesota. *Flicker* 12:21-23.

BOLLES, F. 1890. Barred owls in captivity. *Auk* 7:101-114.

BROWN, W.H. 1962. Parental care by a barred owl. *Iowa Bird Life* 32:58.

BRUSH, G.S., C. LENK AND J. SMITH. 1980. The natural forests of Maryland: an explanation of the vegetational map of Maryland. *Ecol. Monogr.* 50:66-92.

CAHN, A.R. AND J.T. KEMP. 1930. On the food of certain owls in east-central Illinois. *Auk* 47:323-328.

CALDWELL, L.D. 1972. Diurnal hunting by a barred owl. *Jack Pine Warbler* 50:93-94.

CARTER, J.D. 1925. Behavior of the barred owl. *Auk* 42:443-444.

Craighead, J.J. and F.C. Craighead, Jr. 1969. Hawks, owls, and wildlife. Dover Publ, Inc. New York.

Dunstan T.C, and S.D. Sample 1972. Biology of barred owls in Minnesota. *Loon* 44:111-115.

ERRINGTON, P.L. 1932. Food habits of southern Wisconsin raptors. Part I. Owls. *Condor* 34:176-186.

_____AND M. MCDONALD. 1937. Conclusions to the food habits of the barred owl in Iowa. *Iowa Bird Life* 7:47-49.

FORSMAN, E. 1975. A preliminary investigation of the spotted owl in oregon. M.S. thesis, Oregon State Univ. 127 pp.

FULLER, M.R. 1979. Spatiotemporal ecology of four sympatric raptor species. Ph.D. dissertation, Univ. Minnesota. 220 pp.

HAMERSTROM, F. 1972. Birds of prey of Wisconsin. Wisc. Dept. Nat. Res.

_____. 1973. Diurnal sleep rhythm of a young barred owl. *Auk* 90:899-900.

HAMERSTROM, F.N., JR. AND F. HAMERSTROM. 1951. Food of young raptors on the Edwin S. George Reserve. *Wilson Bull.* 63:16-25.

HENDERSON, G. 1933. Boldness of barred owls when danger threatens young. *Wilson Bull.* 45:143.

HILDEN, O. 1965. Habitat selection in birds. *Annals Zool. Fenn.* 2:53-75.

HULL, C.H. AND N.H. NIE (eds). 1981. SPSS update 7-9. McGraw-Hill Book Co., New York. 402 pp.

INGRAM, C. 1959. The importance of juvenile cannibalism in the breeding biology of certain birds of prey. *Auk* 76:218-224.

JAKSIC, F.M. 1982. Inadequacy of activity time as a niche difference: the case of diurnal and nocturnal raptors. *Oecologia* 52:171-175.

JAMES, F.C. 1978. On understanding quantitative surveys of vegetation. *Amer. Birds* 32:18-21.

_____ AND H.H. SHUGART, JR. 1970. A quantitative method of habitat description. *Audubon Field Notes* 24:727-736.

JANIK, C. 1980. Nesting biology and behavior of woodland raptors in western Maryland. M.S. Thesis, Frostburg State College, Maryland. 87 pp.

_____ AND J.A. MOSHER. 1982. Breeding biology of raptors in the central Appalachians. *Raptor Research* 16:18-24.

KORSCHGEN, L.J. AND H.B. STUART. 1972. Twenty years of avian predator-small mammal relationships in Missouri. *J. Wildl. Manage.* 36:269-282.

LEDER, J.E. AND M.L. WALTERS. 1980. Nesting observations for the barred owl in western Washington. *Murrelet:* 110-112.

LEDUC, P. 1970. The nesting ecology of some hawks and owls in southeastern Minnesota. *Loon* 42:48-62.

LINDSEY, A.A., S.D. BARTON AND S.R. MILES. 1958. Field efficiencies of forest sampling methods. *Ecology* 39:428-444.

MENDALL, H.L. 1944. Food of hawks and owls in Maine. *J. Wildl. Manage.* 8:198-208.

MURRAY, G.A. 1976. Geographic variation in the clutch sizes of seven owl species. *Auk* 93:602-613.

NICHOLLS, T.H. AND D.W. WARNER. 1972. Barred owl habitat use as determined by radiotelemetry. *J. Wildl. Manage.* 36:213-224.

NIE, N.H., C.H. HULL, J.G. JENKINS, K. STEINBRENNER, AND H. BENT (eds.). 1975. Statistical package for the social sciences. McGraw-Hill Book Co., New York.

ROBERTSON, W.B. 1959. Barred owl nesting on the ground. *Auk* 76:227-230.

SIEGEL, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., New York.

SOUCY, L., JR. 1976. Barred owl nest. *North Am. Bird Bander* 1:68-69.

STINSON, C.H. 1979. On the selective advantage of fratricide in raptors. *Evolution* 33:1219-1225.

STONE, K.M. AND E.D. MATTHEWS. 1977. Soil survy of Allegany County, Maryland. USDA, Soil Cons. Service. 234 pp.

TEMPLE, S.A. 1977. Manipulating behavioral patterns of endangered birds. A potential management technique. Pp. 435-443 *In* S. A. Temple (ed.), Endangered birds. Management techniques for preserving threatened species. Univ. Wisc. Press, Madison.

TITUS, K. 1980. Nest site habitat selection by woodland hawks in the central Appalachians. M.S. thesis, Frostburg State College, Maryland. 67 pp.

_____ AND J.A. MOSHER. 1981. Nest site habitat selection by woodland hawks in the central Appalachians. *Auk* 98:270-281.

WILSON, K.A. 1983. Owl studies in Ann Arbor, Michigan *Auk* 55:187-197.

Cooperative Wildlife Rsh. Lab, Southern Illinois Univ. Carbondale, IL 62901. Address of second author: Appalachian Environmental Lab, Univ. of Maryland, Frostburg State College Campus, Frostburg, MD 21532. Present address of second author: Savage River Consulting, Box 71, Frostburg, MD 21532.

Received 8 March 1983; Accepted 10 May 1984.

TELEMENTRY OF HEART RATES IN LARGE RAPTORS: A METHOD OF TRANSMITTER AND ELECTRODE PLACEMENT

KEVIN T. PATTON, WALTER C. CRAWFORD, JR., AND WILLIAM SAWYER

ABSTRACT - Heart rates of the Red-tailed Hawk (*Buteo jamaicensis*) and Barred Owl (*Strix varia*) were monitored telemetrically. The most acceptable data were received from devices whose electrodes were anchored within the thoracoabdominal space near the apex of the heart (primary lead) and dorsum (reference lead). Easily assembled plastic backpacks and leather harnesses were designed to be comfortable to birds and also to be resistant to damage from beaks and talons.

Previously developed methods for monitoring heart rate telemetrically (Sawby et al. 1974; Busch et al. 1978; Kanwisher et al. 1978) proved unsuccessful for large raptors for several reasons. First, unsuitable arrangement of electrode leads gave unreliable results (Sawby et al. 1974) and were too difficult and time-consuming to place to be of practical value (Busch et al. 1978). Secondly, an easy, reliable method of attaching the transmitting devices to the dorsum of each bird has been lacking. In addition, Kanwisher, et al. (1978) described a method which was vague on electrode placement and included an unprotected backpack. Our objectives were, therefore, to develop a more satisfactory placement of electrodes and a safe, economical backpack and harness for transmitter attachment.

MATERIALS AND METHODS

Electronics. — Two electrodes, 1 acting as primary lead and the other as reference lead, were surgically implanted. The primary lead consisted of a 34 cm strand of Teflon-E insulated 7 x 40 cm silver coated copper wire (Beldon Electronics, Geneva, IL 60134) terminating at 1 end with a 1 mm round pin (Vector Electronic Co., Inc., Sylmar, CA 91342) and a No-Knot Eyelet fish hook (Wilson-Allen Corp., Windsor, MO) at the other end (Sawby et al. 1974), constituting a barbed-needle electrode (Fig. 1). The reference lead was constructed with the same material except that the No-Knot Eyelet was replaced with a 0.5 cm loop of uninsulated wire, constituting a circle electrode (Fig. 1). These electrodes detected action potential of high amplitude S-waves of the electrocardiogram of the raptor and the attached transmitter module converted information into short RF pulses which were transmitted in the range of 148-149 MHz (J. Stuart Enterprises, Grass Valley, CA 95945). The transmitter had a mass of 20 g and measured 2.0 x 1.5 x 8.5 cm (Fig. 1).

Surgical Procedure. — Subjects wre anesthetized with an intramuscular injection of Ketamine Hydrochloride (Fowler 1978) and Acepromazine Maleate into the muscles of the leg. The Acepromazine Maleate reduces the muscle spasms resulting from the use of Ketamine Hydrochloride as the principal anesthetic (Fowler 1978). Satisfactory dosages were 15-25 mg/kg of a 10:1 Ketamine/Acepromazine solution.

A 1 cm incision was made along the abdominal midline 0.5 cm posterior to the sternum, roughly following the method proposed by Sawby et al. (1974). Using a curved hemostat, the barbed-needle electrode of the primary lead was inserted cranially through the incision into the abdominal cavity (Fig. 2) and advanced along the peritoneal surface of the keel, to a position as close as possible to the apex of the heart, then imbedded into the sternum. The remainder of the lead was passed laterally from the incision subcutaneously to a point just posterior to the left wing. It was usually necessary to open this track with a blunt probe before pushing the lead through. A 0.5 cm incision was made to allow the lead to exit. This lead was similarly tunneled from the point of lateral incision to a point on the median of the dorsum. Another incision was made to allow exit of the lead and removal of the slack All incisions were closed with 3-0 gut suture.

The circle electrode on the reference lead was anchored subcutaneously with 3-0 gut suture to muscle tissue at the point of the dorsal incision (Fig. 2). This incision was then closed with 3-0 gut suture, leaving both leads protruding out of the skin. The procedure usually lasted about 20 min.

Salvaged raptor carcasses were dissected prior to this study to practice locating heart and surrounding structures before beginning on a live bird. Also, domestic fowl (*Gallus* sp.) were implanted with electrodes to perfect surgical technique and electrode placements.

Backpack and Harness. — A backpack was constructed of 10 cm of 2.6 cm (i.d.) clear plastic tubing (Kirkill, Inc., Downy, CA 90241) and end-caps consisting of plastic 35 mm film canisters. A leather harness was made by riveting 2 strips of leather (each 1.5 cm wide) to the dorsal wall of the backpack (Fig. 3). The contact pins of both leads were passed through a hole in the ventral wall of the plastic tubing and connected to the transmitter inside of the tubing. Leather straps were passed around the wings of the bird to the ventrum and riveted together (Fig. 2).

Data Collection. — Signals were received by a portable unit consisting of 3 components: a hand-held antenna, a radio receiver, and a strip-chart recorder (J. Stuart Enterprises, Grass Valley, CA 95945). The receiver was a Telonics Model TR-2 direct-frequency reading, synthesized triple heterodyne, AC/DC receiver which measured 11.5 x 5.1 x 18.0 cm. The recorder was a Gulton Model 288 DC recorder which utilized pressure sensitive strip-chart paper to record an instantaneous average of heart rate in beats/min at 2-sec intervals. This unit measured 15.3 x 22.9 x 19.1. The normal DC mode of the recorder was converted to AC by the use of a current transformer. A programmable household timer (Radio Shack/Tandy, Ft. Worth, TX 76113) was used to turn on the recorder at previously determined intervals. The graphs produced resembled that in Fig. 4.

Two Red-tailed Hawks, 1 Great Horned Owl (*Bubo virginianus*) and 1 Barred Owl were affixed with transmitters. All were victims of crippling injuries to 1 wing and thus incapable of flight and had been received from the rehabilitation unit of the Raptor Rehabilitation and Propagation Project, Inc. Each bird was housed in an outdoor enclosure (2.5 x 5.0 x 2.5 m) after implantation and recovery.

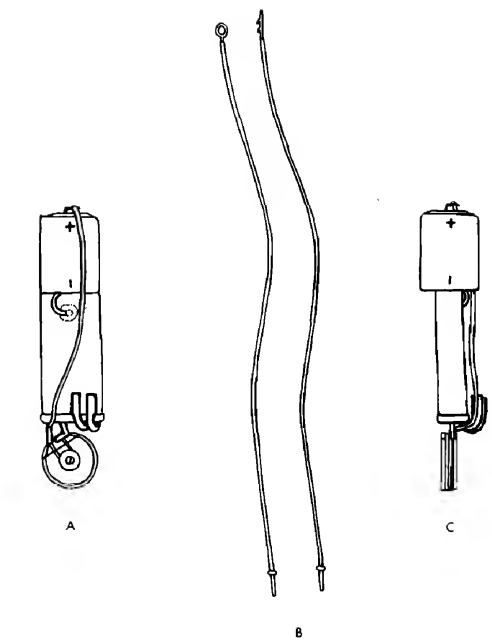

Figure 1. A and C: Bottom and side views of transmitting device; B: Primary lead and reference lead.

RESULTS AND DISCUSSION

Signals from the heart rate transmitter were received up to a distance of 1 km. Lithium batteries in each of the 3 units used were in continuous operation for over 1 yr, with no apparent reduction in performance. The backpacks and leads, when properly placed, remained functional for at least 1 mo. The backpacks and leads were checked daily for damage. We believe that the method of recording was less complex to operate and more easily monitored than day-to-day methods previously reported (Sawby et al. 1974, Busch et al. 1978, Kanwisher et al. 1978).

Difficulty in implanting the barbed-needle electrode of the primary lead was encountered with older birds whose skeletons had undergone more ossification. Implanting the electrode in the lateral edge of the sternum may prove adequate if normal implantation is not possible.

Placement of the leads proved critical. The primary lead did not respond satisfactorily if placed outside the abdominal cavity or if placed loosely inside the abdominal cavity. The barbed-needle electrode on the primary lead provided a secure long-lasting anchor inside the body cavity in proximity to the apex of the heart. Care was taken during the implantation to prevent accidental injury to internal structures, especially pericardium.

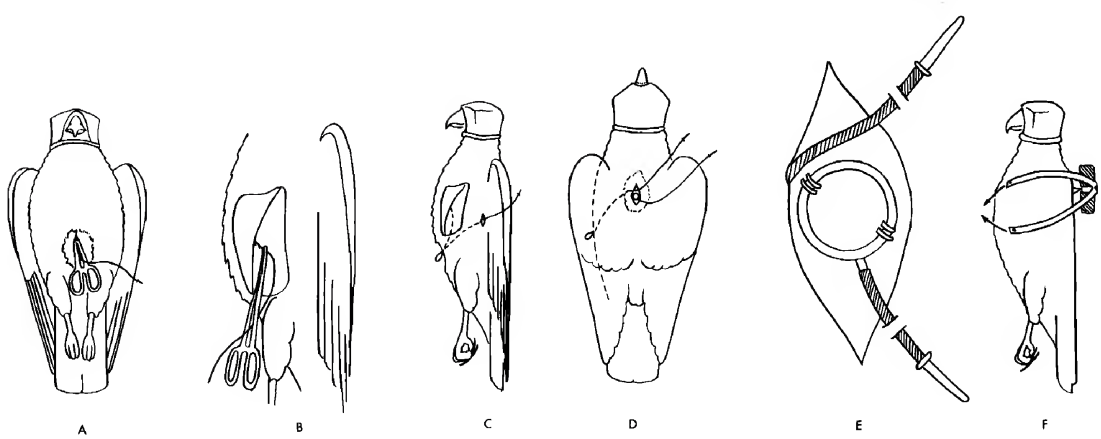

Figure 2. A: Ventral insertion of internal (primary) lead near end of keel; B: Side view of barbed-needle electrode of internal lead being pushed into dorsal side of keel through ventral incision; C: Subdermal insertion of internal lead toward dorsal exit point; D: Dorsal view showing exit of internal lead and surgical implantation of external (reference) lead; E: Enlarged view of subdermal attachment of reference lead and exit of primary lead; F: Attachment of harness containing transmitter.

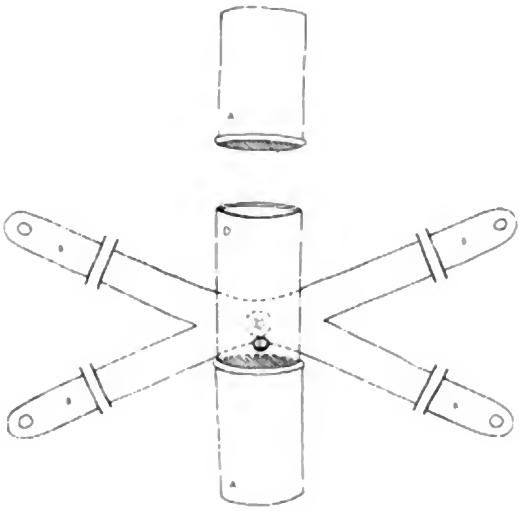

Figure 3. Construction of Backpack and Harness; A: Plastic film canisters; B: Leather straps; C: Metal rivet; D: Clear plastic tubing; E: Hole for exit of leads.

Figure 4. Heartrate data (heartbeats/min) obtained from a captive Red-tailed Hawk (*Buteo jamaicensis*) at a distance of 15 m.

The reference lead, if anchored in any area but the surface of dorsal muscles, did not provide adequate grounding for a proper response of the system. Interference by the electromyogram of the pectoral muscle tissue was assumed to have prevented satisfactory ventral placement of this lead, since difficulty was encountered only when that muscle was contracting. Obviously, this would be unacceptable in applications involving birds in flight. The method described might possibly be used to monitor the heart rate of birds in flight, however, given the lack of electromyogram interference and range of signal transmission.

Construction of the backpack/harness assembly was very simple and economical. Total cost was under $1 US. The plastic materials utilized endured the efforts of the birds to remove or dismantle them with beak or talon without contributing excessive mass. A very snug fit is required to prevent the bird from gaining access to the leads where they exit the dorsal incision and enter the backpack.

ACKNOWLEDGEMENTS

Artwork was done by David Huth. Equipment was funded through a cooperative aid agreement with the North Central Forest Experiment Station, USDA Forest Service. Dr. Gary Duke kindly provided constructive criticism of our preliminary drafts.

LITERATURE CITED

BUSCH, D.E., W.A. DEGRAW AND N.C. CLAMPITT. 1978. Effects of handling disturbance stress on heartrate in the Ferruginous Hawk (*Buteo regalis*). *Raptor Research* 12:122-125.

FOWLER, M.E. 1978. Restraint and handling of wild and domestic animals. Iowa State University Press. Ames, IA 332 pp.

KANWISHER, J.W., T.C. WILLIAMS, J.M. TEAL AND K.O. LAWSON, JR. 1978. Radiotelemetry of heart rates from free-ranging gulls. *Auk* 95:288-293.

SAWBY, S.W. AND J.A. GESSAMAN. 1974. Telemetry of electrocardiograms from free-living birds: a method of electrode placement.

Raptor Rehabilitation and Propagation Project, Inc., Tyson Research Center, Eureka, MO 63025.

Received 25 August 1983; Accepted 27 April 1984.

ELECTRORETINOGRAMS AND RETINAL STRUCTURE OF THE EASTERN SCREECH OWL (*Otus asio*) AND GREAT HORNED OWL (*Bubo virginianus*)

STEVEN J. AULT

ABSTRACT — Electroretinograms (ERGs) were recorded from 2 species of owls: Eastern Screech Owl (*Otus asio*) and Great Horned Owl (*Bubo virginianus*). Dark adaptation and flicker stimuli were used to determine retinal activity and to infer retinal structure. The dark adaptation results showed typical patterns associated with retinas composed primarily of rods. This was indicated by the late regeneration of the scotopic b-wave. Flicker ERGs, however, also indicated a residual cone component. This was indicated by the one-to-one response at high luminance levels and high flicker frequencies. The ERG data confirm existing histological observations of high rod numbers and few cones in the retinas of nocturnal owls.

Owl retinas have been examined histologically by a number of investigators (Bornshein and Tansley 1961; Hocking and Mitchell 1961; Oehme 1961; Fite 1973; Yew et al. 1977; Bowmaker and Martin 1978). All reported retinas with high concentrations of rods, as would be expected for basically nocturnal animals. However, Fite (1973) and Oehme (1961) point out that owl retinas do possess very small concentrations of cones, even in the most nocturnal species.

Few electroretinographic studies have been performed on owls. Bornshein and Tansley (1961) obtained ERGs from Short-eared Owl (*Asio flammeus*) and compared response of the retina to that of the pigeon. These authors also correlated the ERG results with histological preparations of the owl and pigeon retinas. The ERGs and the histological examination revealed a retina composed predominantly of rods in the Short-eared Owl. Martin and Gordon (1975) recorded ERGs from the nocturnal Tawny Owl (*Strix aluco*) to determine its retinal spectral sensitivity. The ERG data supported earlier findings (Martin 1974; Martin and Gordon 1974) that the Tawny Owl possesses a retina with cone receptors that are present in large enough numbers to contribute to the visual response.

The purpose of this investigation was to record electroretinographic activity of the Eastern Screech Owl and Great Horned Owl, two species not previously investigated. Correlation of the ERG data with retinal structure of these species was made in an attempt to better define the relative role of the rods and cones in the visual process of these owls.

MATERIALS AND METHODS

Subjects and Anesthesia. — One Eastern Screech Owl and one Great Horned Owl were used for electroretinography. Both were anesthetized with an anesthetic mixture containing Ketamine (10 mg/ml), Acepromazine (0.1 mg/ml), and Xylazine (1.0 mg/ml). Dosage was 1 ml/kg body weight, administered IM. Average duration of anesthesia was approximately 1 h.

Each subject was placed into a light-tight, electrically grounded box, and a corneal electrode was placed on the eye. Space between the cornea and electrode was flooded with a saline (0.9% NaCl) conducting solution. A reference electrode was placed in the skin of the ear flap or in the skin of the ear canal. A ground electrode was inserted in the wing skin. A fiber optic light guide was hlaced a few mm from the cornea.

Electroretinograph. — The light source was a 300 watt tungsten-halogen lamp that could deliver steady, single-flash, or flickering stimuli. Flicker stimuli were produced by a motor-driven disc that interrupted the light to give equal time on and off. The light beam was focused upon a fiber optic light guide which delivered light to the subject's eye in Maxwellian view (Armington 1974). The light beam wavelength and intensity were adjusted by the use of various color and neutral density filters. Unfiltered light intensity from this apparatus was approximately 1.076×10^4 millilamberts (mL) (1 mL = 0.001 lumens/cm^2).

The recording electrodes used were silver pedestal corneal contact lens systems. Reference and ground electrodes were silver skin needle probes. Signals from the electrodes were channeled through a Tektronix TM 504 pre-amplifier. The signal was amplified and displayed on a Tektronix 5103N dual-trace storage oscilloscope. Traces were permanently recorded by Polaroid photography.

Procedure. — Two tests commonly used in electroretinography, dark adaptation and flicker stimuli, were used. Dark adaptation tests were used to observe changes in the ERG as the retina adjusted to darkness. The eye was first pre-adapted to light for 5 min to insure bleaching of the photopigments. Pre-adaptation retinal illuminance was approximately 1.076×10^3 mL for the Eastern Screech Owl and 1.076×10^1 mL for the Great Horned Owl. Different intensities were used for both owls to assess the effectiveness of such intensities for pre-adaptation, single-flash (20 msec duration) stimuli attenuated with a Kodak #2 neutral density filter and a Kodak #26 gel film red filter, were delivered at widely spaced intervals (see Figs. 1-3) to the eye to observe the retina's increasing sensitivity to darkness. After 20-30 min, full-intensity single-flash stimuli of red (Kodak #26 gel film), blue (Kodak #47, 47A, 47B gel film) and white (no filters) were given successively to assess the degree of photopic (cone) and scotopic (rod) recovery.

The second test utilized flickering stimuli of various intensities and flicker frequencies. Various neutral density filters, but no color filters, were used.

Histology. — The retinas of a Great Horned and Eastern

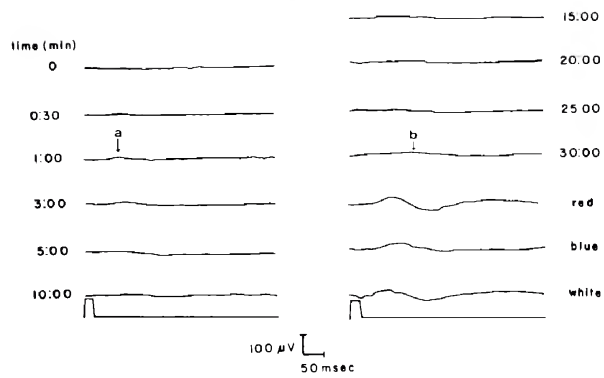

Figure 1. ERGs during dark adaptation in the Eastern Screech Owl. Time indicates minutes into dark adaptation. Stimulus: 1.076 x 10^4 mL attenuated with #2 neutral density filter and #26 red filter; 20msec duration. a) Slight regeneration of photopic b-wave after 1 minute into dark adaptation. b) Slight regeneration of scotopic b-wave after 30 minutes into dark adaptation.

Screech Owl were examined histologically. The Great Horned was the same animal used in the ERG study. The subjects were euthanized with lethal injection of Ketamine and enucleated. The posterior portion of the eye was cut away and fixed in Bouin's solution. The tissue was dehydrated in a graded ethanol series and cleared in cedarwood oil. Portions of peripheral retina were embedded in paraffin, sectioned meridionally at 5 m on a rotary microtome and stained with Hematoxylin and Eosin.

RESULTS

Dark Adaptation. — The ERGs from dark adaptation tests for both subjects showed very early low-amplitude responses which peaked at around 1-2 min into dark adaptation (Figs. 1a, 2a). Also, late appearing (between 20 and 30 min into dark adaptation) low-amplitude waveforms were observed (Figs. 1b, 2b). The final red, blue, and white stimuli produced waveforms of low amplitude.

Flicker Stimuli. — A change in waveforms were observed as the flickering stimuli were increased from low to high intensities and flicker frequencies; this was best demonstrated by the Eastern Screech Owl. At low intensities and low flicker frequencies, waves were evident as they followed the stimuli on a 1:1 basis (Fig. 3a). There was a fusion of this response as intensities and flicker frequencies increased, with a subsequent waveform taking over at high intensities and high flicker frequencies (Fig. 3b). The Great Horned Owl also displayed the above pattern, but with less clarity (Fig. 4).

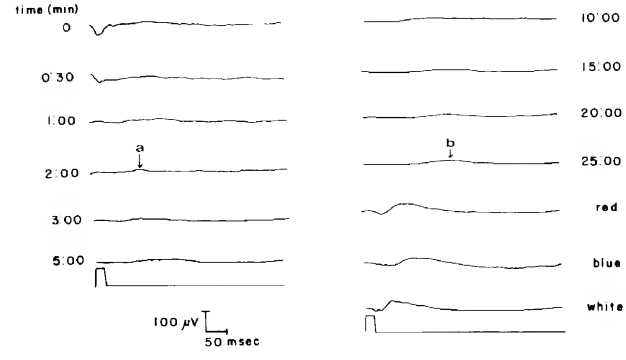

Figure 2. ERGs during dark adaptation in the Great Horned Owl. Time indicates minutes into dark adaptation. Stimulus: 1.076 x 10^4 mL attenuated with #2 neutral density filter and #26 red filter; 20 msec duration. a) Slight regeneration of photopic b-wave after 1-2 minutes into dark adaptation. b) Slight regeneration of scotopic b-wave after 20-30 minutes into dark adaptation.

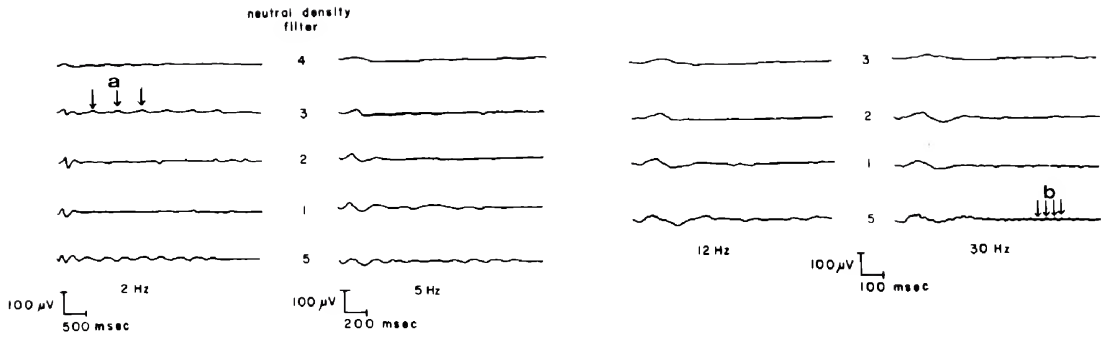

Figure 3. Flicker ERGs of the Eastern Screech Owl. a) Arrows indicate one-to-one response of waveforms to individual flickers at low intensity and low flicker frequency. b) Arrows indicate one-to-one response of waveforms to individual flickers at high intensity and high flicker frequency. 1.076 x 10^4 mL light source attenuated with indicated neutral density filters.

Histology. — The retinal layers of the Eastern Screech Owl could be clearly discerned histologically (Fig. 5). Retinas were composed primarily of rods; indicated by the elongated and cylindrical morphology of their outer segments in the receptor layer. The nuclei in the outer nuclear layer were also identified as rod nuclei because they were typically more elongated and were fairly evenly distributed throughout the outer nuclear layer (Walls 1942; Duke-Elder 1958). The rod nuclei of the Great Horned Owl were extremely elongated and closely packed.

A few cones were also seen in owl retinas. These were identified by their nuclei, which are typically rounder than rod nuclei and lie adjacent to the external limiting membrane. In all sections, cones were always few in number and were greatly outnumbered by the high density of rods.

DISCUSSION

The typical ERG waveform is composed of the a, b and c waves. The initial negative deflection (a-wave) is followed by a positive deflection (b-wave) normally of greater amplitude. The late-occuring

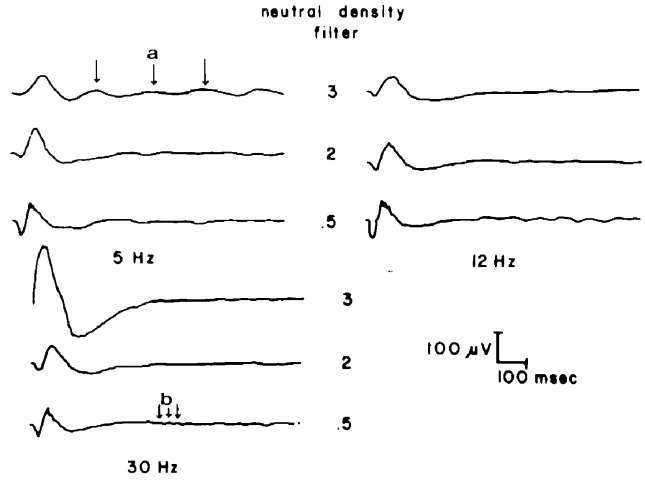

Figure 4. Flicker ERGs of the Great Horned Owl. a) Arrows indicate one-to-one response of waveforms to individual flickers at low intensity and low flicker frequency. b) Arrows indicate one-to-one response of waveforms to individual flickers at high intensity and high flicker frequency. 1.076 x 10^4 mL light source attenuated with indicated neutral density filters.

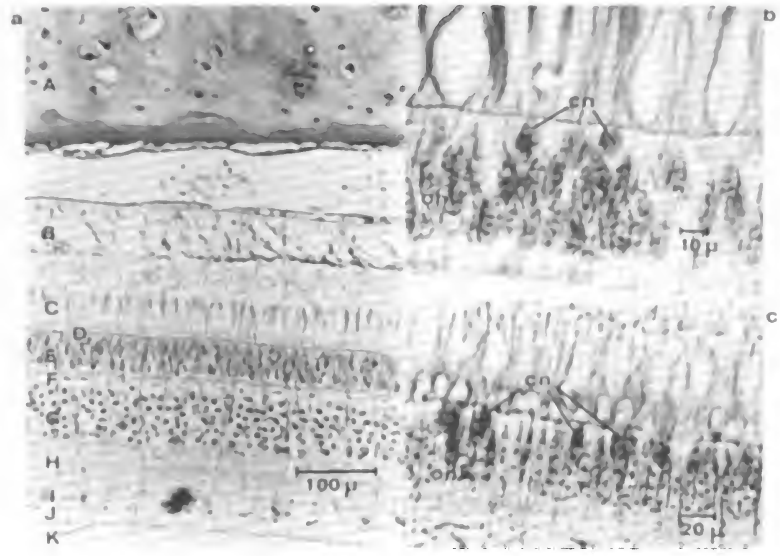

Figure 5. a). Layers of the Eastern Screech Owl retina. A) cartilaginous cup; B) pigment epithelium; C) receptor layer; D) external limiting membrane; E) outer nuclear layer; F) outer plexiform layer; G) inner nuclear layer; H) inner plexiform layer; I) ganglion cell layer; J) nerve fiber layer; and K) internal limiting membrane (200x); b) Eastern Screech Owl and c) Great Horned Owl retinas. cn = cone nuclei; onl = outer nuclear layer (primarily rod nuclei). (787.5x and 500x respectively).

positive deflection (c-wave) is not commonly evaluated in comparative studies. Brown (1968) explained that the a-wave is produced in the receptor cell layer, the b-wave through bipolar cell activity, and the c-wave by metabolic activity of the pigment epithelium. The a- and b-waves can be further subdivided into photopic (cone generated) and scotopic (rod generated) components. In general, the photopic components have shorter latencies and steeper slopes than scotopic components (Armington 1974). These patterns were evident in the owls studied (Figs. 1, 2)

The dark adaptation results revealed typical patterns associated with retinas composed predominantly of rods. The late regenerating wave forms were most likely scotopic b-waves suggesting that rods were regenerating after having been bleached during light adaptation. Latency of these b-waves suggested the response was from the scotopic system. Longer latency or implicit time (approximately 100 msec) is indicative of a scotopic rather than photopic b-wave (approximately 50-70 msec). Earlier low-amplitude responses were probably cone responses because of their early appearance during dark adaptation. Latency of these responses was also shorter than the scotopic responses, again suggesting generation by a cone component. As dark adaptation progressed, these early responses diminished and were replaced by the scotopic responses. After 25-30 min, there was still no complete regeneration of the scotopic responses in either owl, denoting that many of the rods were not yet adapted to the dark. The reduced effect of the blue light on the scotopic system also verified this since blue light is primarily a rod stimulator. These observations suggested a retina predominated by rods, but with a small cone component. However, it could mean that the initial light adapting intensity was too high. This seems unlikely since an absence of complete regeneration of the scotopic response was also observed in the Great Horned Owl which was exposed to a lower light-adapting intensity.

The shift from scotopic to photopic systems during the flicker procedures was indicated by a decrease in latency and an increase in amplitude of the initial b-wave as flicker frequencies and intensities were increased. The initial a-wave also became more prominent at higher flicker frequencies and intensities, providing further indication of the shift to the photopic system (Armington 1974). The rods and cones were also able to follow the individual flickering stimuli. At low intensities and low flicker

frequencies, rods were able to follow individual flickers, having not yet exceeded their critical flicker fusion frequency. As intensity and/or frequency was increased, rods "fused" the stimuli. Fusion occurred when the receptors could no longer respond to individual flickers on a 1:1 ratio but instead responded to them as if there was one constant stimulus. At high intensities and high flicker frequencies, cone response became dominant and was able to follow individual flickers since they possess a higher critical flicker fusion frequency than rods (Armington 1974). Histological results in combination with the ERG data indicated that the retinas were predominantly composed of rods. This supports the findings of previous workers (Bornshein and Tansley 1961; Hocking and Mitchell 1961; Oehme 1961; Fite 1973; Yew et al. 1977; Bowmaker and Martin 1978) who histologically demonstrated a retina composed predominantly of rods in the Great Horned Owl and other owl species. However, histological results and ERG data also demonstrated the presence of a cone component that was small but active.

My results and those of Bowmaker and Martin (1978) and Martin and Gordon (1975) verify that the retina of owls, even the most nocturnal species, possess cones in numbers large enough to contribute to the visual process. Existence of such a cone component could be the remnants of an ancestral cone-dominated retina. Nocturnal owls such as screech and Great Horned Owls are occasionally active during the day. It is reasonable to assume that the few cones that are present contribute to the owl's visual process in the brighter illumination of daylight hours.

ACKNOWLEDGMENTS

I extend special thanks to Charles J. Parshall, Animal Specialty Clinic, Richfield, Ohio, for help and expertise with electroretinography and to Richard F. Nokes, The University of Akron, who assisted with anesthesiology. F. Scott Orcutt, John H. Olive, Steven P. Schmidt, Edwin W. House, and Carolyn Wilson made positive critical comments on the manuscript. This study was supported in part by a Grant-in-Aid of Research from Sigma Xi, The Scientific Research Society.

LITERATURE CITED

ARMINGTON, J.C. 1974. The Electroretinogram. New York: Academic Press.

BORNSHEIN, H. AND K. TANSLEY. 1961. Elektroretinogramm und Netzhautstruktur der Sumpfohreule (*Asio flammeus*). *Experientia.* 17: 185-187.

BOWMAKER, J.K. AND G.R. MARTIN. 1978. Visual pigments and colour vision in a nocturnal bird, *Strix aluco* (Tawny owl). *Vision Research* 18:1125-1130.

BROWN, K.T. 1968. The Electroretinogram: Its Components and Their Origins. *Vision Research* 8:633-677.

DUKE-ELDER, S. 1958. System of Ophthalmology. Vol. 1: The Eye in Evolution. St. Louis: C.V. Mosby.

FITE, K. 1973. Anatomical and Behavioral Correlates of Visual Acuity in the Great Horned Owl. *Vision Research* 13:219-230.

HOCKING, B. AND B.L. MITCHELL 1961. Owl Vision. *Ibis.* 103a, 284-288 .

MARTIN, G.R. 1974. Color Vision in the Tawny Owl (*Strix aluco*). Journal of Comparative and Physiological Psychology. 86, 133-142.

MARTIN, G.R. AND I. GORDON 1974. Increment-threshold Spectral Sensitivity in the Tawny Owl (*Strix aluco*). *Vision Research* 14:615-620.

_____ 1975. Electroretinographically Determined Spectral Sensitivity in the Tawny Owl (*Strix aluco*). *Journal of Comparative and Physiological Psychology* 89:72-78.

OEHME, H. 1961. Vergleichend-histologiche Untersuchungen an der Retina von Eulen. Die Zoologischen Jahrbucher, Abt. 2, der *Anatomie und Ontogenie* 79:439-478.

WALLS, G.L. 1942. The Vertebrate Eye. Cranbrook Institute of Science. Bulletin #19.

YEW, D.T., H.H. WOO AND D.B. MEYER 1977. Further Studies on the Morphology of the Owl's Retina. *Acta Anatomica* 99:166-168.

Department of Biology, The University of Akron, Akron, Ohio 44325. Present address: Department of Biology, Idaho State University, Pocatello, Idaho 83209.

Received 8 March 1984; Accepted 1 July 1984.

FOOTPRINTING OF RAPTORS FOR IDENTIFICATION

ERIK H. STAUBER

ABSTRACT - The feet of 15 Peregrine Falcons (*Falco peregrinus*) and 25 Red-tailed Hawks (*Buteo jamaicensis*) were photographed for evaluation of the dorsal scale patterns of their toes. Visual analysis of the middle toes (digit #3) showed recognizeable scale pattern differences between toes from individual birds as well as for all related and unrelated birds. Scale patterns remained unchanged for birds that were available in successive years. It is suggested that the toe scale pattern is unique for any Peregrine Falcon or Red-tailed Hawk and could be used for permanent individual identification.

Methods of differentiating individuals within certain species, including man, have been explored and used for many decades. Artificial markers consisting of either bands, tags, tatoos or hot or cold brands are used to identify individuals when readily identifiable and unalterable natural markers do not exist. However, there are a few species in which each individual has unique, unchanging markings which can be recorded and used effectively for purposes of identification. The most notable example is the use of fingerprinting in humans. Other examples where unique markers have been used for individual identification are the stripe patterns of zebras, the reticulation on the pelage of giraffes, the noseprints on bovine animals, or the dorsal fin shapes and spots on killer whales.

Most birds have scale patterns on their feet and legs, but there is no evidence that the scale pattern of any species has ever been analyzed for the purpose of developing an identification system. The foot scale patterns of Peregrine Falcons (*Falco peregrinus*) and Red-tailed Hawks (*Buteo jamaicensis*) were characterized to determine their usefulness in individual identification.

MATERIALS AND METHODS

Individual birds representing 2 raptor species were chosen for photographic evaluation of the scale pattern of the dorsal aspects of their toes. Birds included in the study were 15 Peregrine Falcons and 25 Red-tailed Hawks. Several were siblings and three were compared in successive years.

Feet were placed so that the entire dorsal aspect of the 3 forward pointing toes (digits # 2,3,4) could be photographed with a close-up lens. Black and white prints (5"x7") were developed and the scale patterns of the toes of all birds were visually analyzed. Only the middle toes (#3) were considered in this study. For evaluation and comparison among individuals, scales of corresponding areas on each toe were characterized according to size, arrangement of scales in relation to adjacent scales, and network of interscale spaces. For convenience of comparison, the area occupied by the dorsal scale(s) closest to the talon was designated as row 1L3 (scale row 1, left foot, digit #3) for the first scale of the middle toe of the left foot and 1R3 for the right foot. Subsequent scales were designated 2L3, 2R3, etc. depending on how many rows of scales were discernible.

RESULTS

Evaluation of photographs taken of the dorsum of the middle toes of 15 Peregrine Falcons and 25 Red-tailed Hawks clearly showed that the scale patterns of each bird differed from the corresponding scale arrangement of all other birds (Fig. 1-4). The number of scale rows varied between the 2 species studied. The evaluation included comparison of 2 sibling (male) Red-tailed Hawks (Fig. 3) and 4 sibling (3 females, 1 male) Peregrine Falcons (Fig. 1 and 2 showing related females E.S., C.F., L.B.). Comparison between right and left foot of each individual bird further revealed that scale patterns were never identical.

Birds which were available the year following the first evaluation and had completed a full molt of their plumage were re-evaluated and shown to have unchanged scale patterns in 2 successive years (Fig. 1 and 4).

Obvious differences for scale patterns for Peregrine Falcons were frequently noted between rows 6 to 8 and commonly between rows 11 to 18 and beyond. The differences in the scales of rows 1-5 and 9 and 10 were more subtle relating primarily to scale size and the ratio of width to length (Fig. 1 and 2). Readily visible differences of scale patterns for Red-tailed Hawks started at rows 5 or 6 and remained distinct for all following rows (Fig. 3 and 4).

DISCUSSION

The principal objective of this study was to develop an identification system for Peregrine Falcons. It was important that the system be simple and could be used for identification of individual birds. Red-tailed Hawks were included primarily because they are a common raptor with a prominent foot scale pattern and were readily accessible for study through the raptor rehabilitation facility at Washington State University.

All birds were identified by the use of photography and by visually comparing the scale patterns

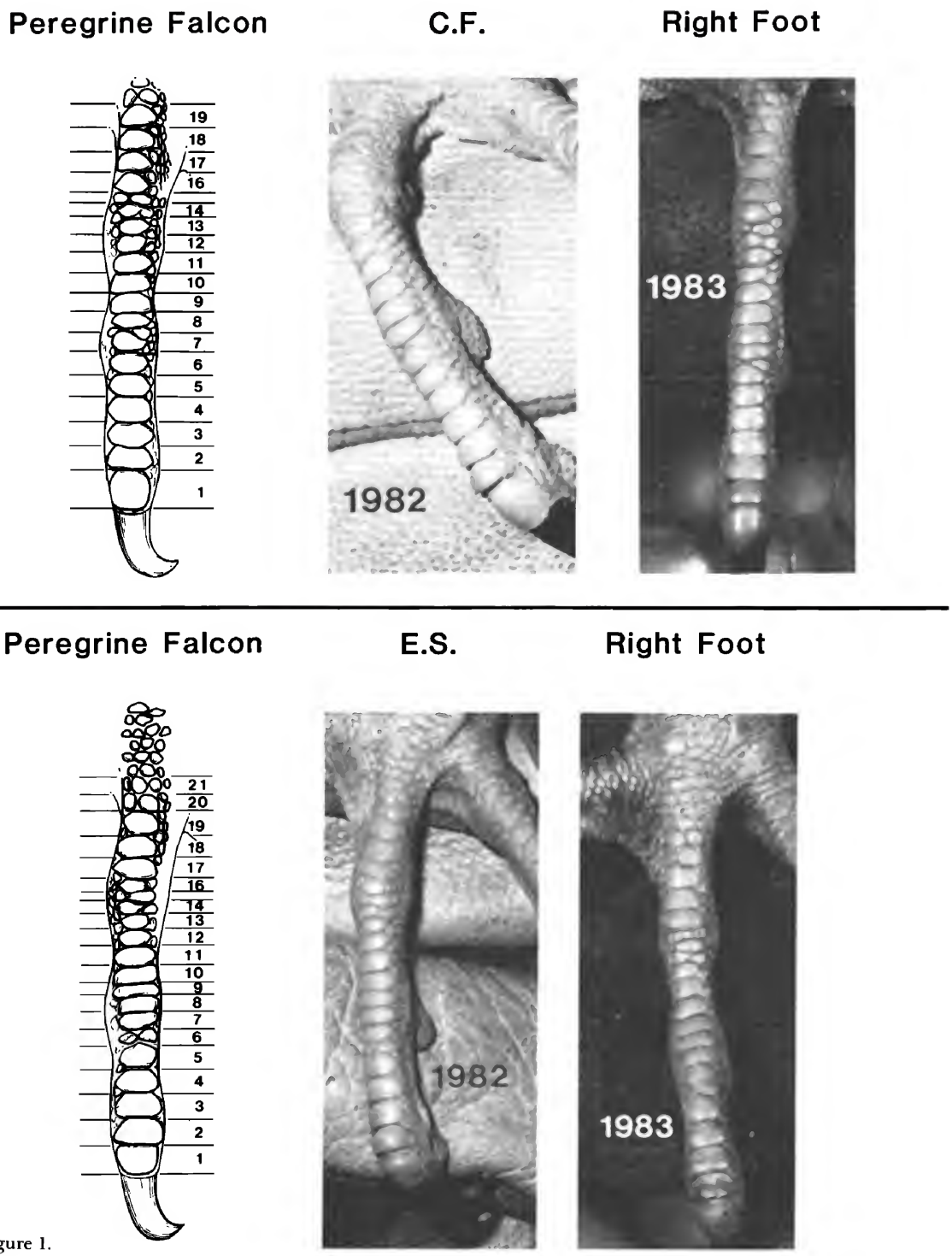
Peregrine Falcon
C.F.
Right Foot
19
18
17
16
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1982
1983
Peregrine Falcon
E.S.
Right Foot
21
20
19
18
17
16
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1982
1983

Figure 1.

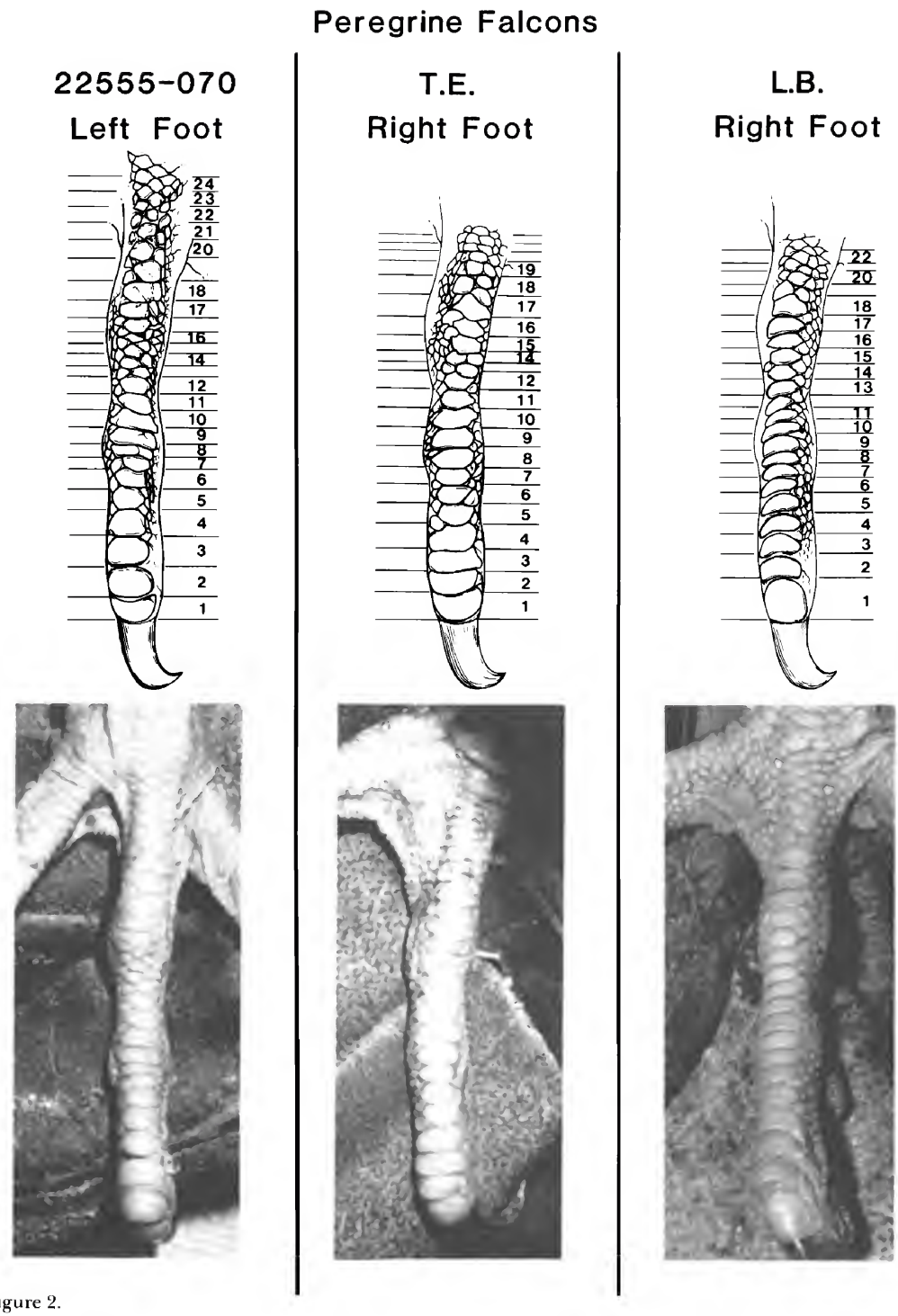
Peregrine Falcons
22555-070
Left Foot
T.E.
Right Foot
L.B.
Right Foot

Figure 2.

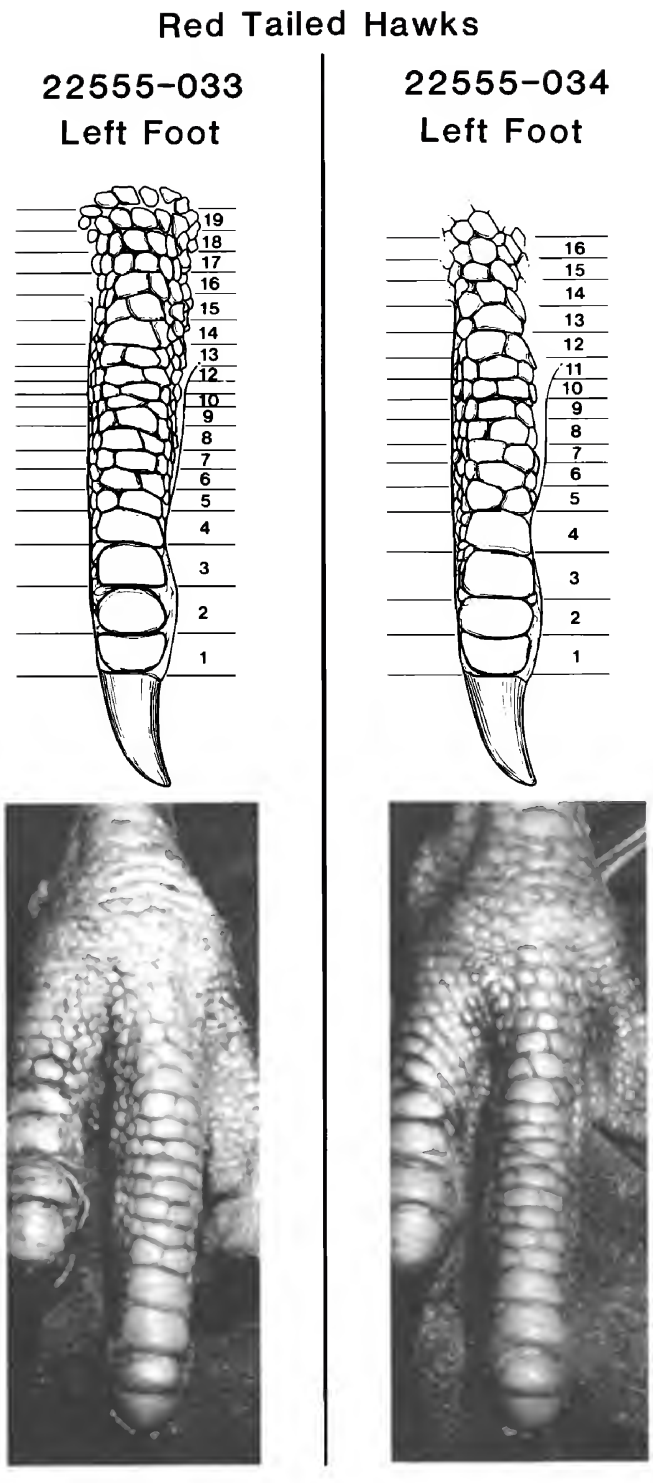
Red Tailed Hawks
22555-033
Left Foot
19
18
17
16
15
14
13
12
10
9
8
7
6
5
4
3
2
1
22555-034
Left Foot
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

Figure 3.

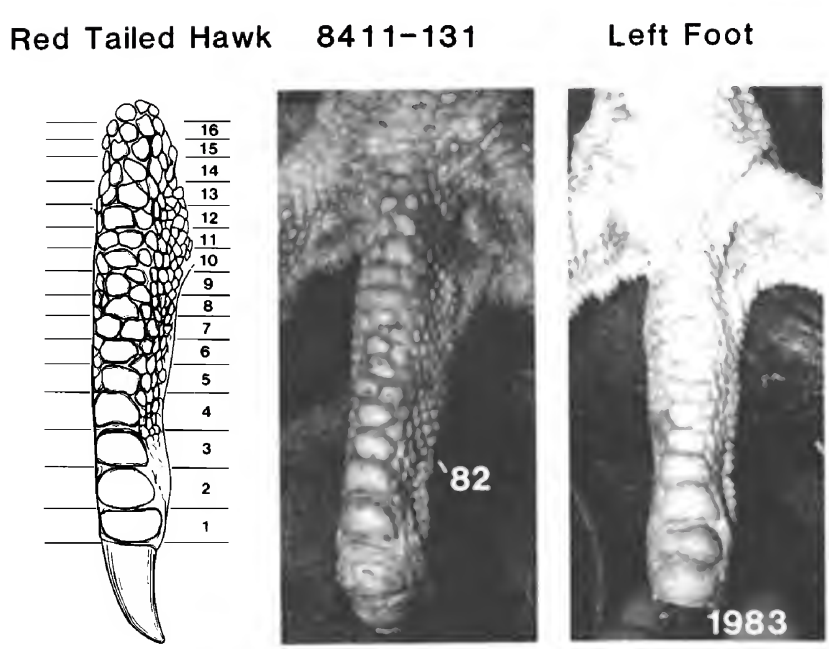

Figure 4.

and shapes of only the middle toe of both feet. In most instances, a mere glance at the scale patterns revealed distinct differences between left and right middle toe of individual birds as well as any 2 birds (including siblings) and these differences remained constant over an extended period.

While it was not difficult to identify birds by photography of the toe scale pattern, it became apparent that magnification of feet and scales was not always uniform since the camera was held at varying distances and angles in the first year of the study. For purposes of this study, measurement of scales was considered unimportant, but scale size and dimensions should certainly be considered in perfecting a reliable identification system. This could be accomplished by making a clay print or by placing the foot on a grid with known dimensions. A study exploring the use of some techniques which will yield a good estimate of the scale size and dimensions is currently underway.

The availability of a reliable identification system for Peregrine Falcons would be of considerable value in light of the status which this bird has occupied in the history of civilization, in general, and in its contemporary management in particular. Proper identification of individual Peregrines held in captivity has been a concern of state and federal wildlife officials for many years. Illegal substitution of lost or deceased birds by replacement of federal bands or the switching of federal bands on stolen birds has been known to occur but nearly impossible to prove. The system of identification described herein would preclude the substitution of one falcon for another and thereby greatly facilitate the management of Peregrine Falcons held in captivity or other bird species to which the system would be applicable. Regardless of whether analysis of foot scale patterns by photography or another system will prove to be the simplest and most feasible approach to the identification of Peregrine Falcons (and other birds), a "footprinting" system offers great promise to document the uniqueness of a raptor so identified.

ACKNOWLEDGMENTS

The author acknowledges the assistance of Dennis Cancellare and Jerry McCollum (photography), Amy Werner (medical illustrator), and William Geoffroy and Lester Boyd for their suggestions. This study was supported in part by funds from the Agricultural Experiment Station, University of Idaho, Moscow. Published with the approval of the Director of the Idaho Agricultural Experiment Station, Moscow, as Research Paper No. 83819.

Department of Veterinary Sciences and WOI Regional Program in Vet. Med. Ed., Univ. of Idaho, Moscow, ID 83843.

Received 30 March 1984; Accepted 25 June 1984.

PSEUDOMEMBRANEOUS GASTRITIS COMPATIBLE WITH (*Clostridium* sp.) IN A CAPTIVE PEREGRINE FALCON

JAMES H. ENDERSON AND MORGAN BERTHRONG, M.D.

ABSTRACT - There have been several instances where the Peregrine Falcon (FALCO PEREGRINUS) used for captive-breeding for many years have died rapidly after being removed from the breeding lofts (W. Burnham, J. Weaver, C. White pers. comm.). This is an account of such an instance where the benefit of a complete necropsy is available and reveals one possible explanation for these losses.

A female Peregrine in captivity over 19 y had produced nearly 100 eggs during the last 10 y while in the loft with a male. Because no eggs were produced in the last year the bird was hooded and transported to a new location. She appeared calm after subsequently consuming a portion of a thawed quail. She seemed relaxed and normal the next morning, but at 1000 h was lethargic. By 1200 h she was breathing heavily and rapidly, and was very weak. She died within the hour.

PATHOLOGIC OBSERVATIONS

Complete autopsy revealed a good state of nutrition. Body weight was 860g. The lateral air sacs were smooth and glistening without parasitic worms or fungi. The oral cavity, crop, esophagus, trachea, lungs and heart were entirely normal. The stomach was empty and contracted with resulting thickening of its mucosal folds. A gray-green exudate was adherent to the mucosl surface. No ulcerations were noted. The remainder of the intestinal tract was grossly normal. The adrenal glands were smaller in comparison to a wild peregrine. The spleen was slightly enlarged. The ovary was small and nodular without developing ova. The kidneys, pancreas, and brain appeared grossly normal.

Histologic examination revealed a fibrinopurulent layer which covered the gastric mucosa where only the most superficial mucosal cells were necrotic and only a superficial mucosl infiltrate of inflammatory cells was observed. The mucosal capillaries were dilated. Gram stains revealed swarms of gram positive rods, large, straight with slightly rounded ends and numerous oval subterminal and central spores, characteristic of a clostridial species within the fibrinopurulent membrane (Fig. 1 and 2). These organisms were not found in the mucosa itself or in the muscularis of the stomach. Large numbers of bacilli, mostly gram positive and similar to those in the stomach, were found in the lumina of both small and large intestine but no mucosal alterations or pseudomembranes were seen. The spleen showed plasmacytoid cells in the red pulp consistent with an immunologic reaction, a so-called "acute splenic tumor".

Kidney sections showed small cysts of a possible congenital cystic disease but large areas of normal glomeruli and tubules suggested normal renal sufficiency. Minimal osteoarthritis was found in the upper humeral joint surface. A small para-adrenal microscopic nodule was found, thought to be a benign neoplasm resembling a human neoplasm known as a carcinoid. Several cysts were found in one of a number of sections of skeletal muscle recognized as those of quiescent avian malaria, possibly *Plasmodium relictum*. These cysts were not surrounded by any tissue reaction and the liver, spleen, bone marrow and heart showed no evidence of active malaria.

DISCUSSION

The development of a pseudomembranous enterocolitis of the intestinal tract with toxic shock, often fatal, has been well recognized in man (Goulston et al. 1965). It was known to occur during the post-opertive period, usually after abdominal surgery, before the advent of antibiotics. Presumably because of an alteration of the bacterial environment, pseudomembranous enteritis or colitis became much more common after widespread use of antibacterial agents in man. At first, cases may have been the result of highly virulent staphylococci but in recent years evidence indicates that most human cases are now the result of overgrowth of clostridial species in the gastrointestinal tract (Bartlett et al. 1978). Epidemics of this condition occurred in Germany immediately after World War II (MacLenan 1962), and in New Guinea (Murrell et al. 1966) from *Clostridium perfringens*, presumably due to ingestion of food massively contaminated with this organism. Recently, most human cases have been shown to be the result of overgrowth of the antibiotic-resistant *Clostridium difficile*, the exotoxin of which has a potent cytotoxic effect and

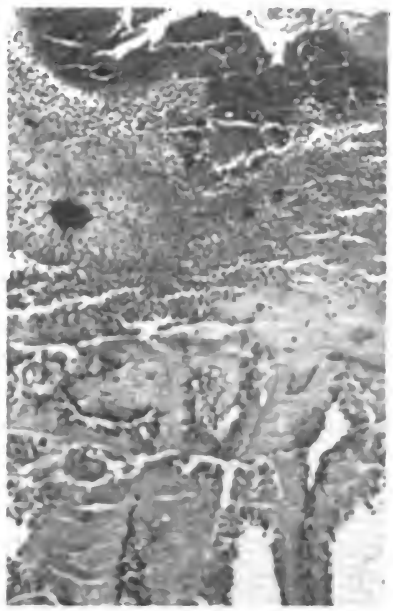

Figure 1. Low power photomicrograph of gastric mucosa covered by a fibrinopurulent pseudomembrane containing swarms of bacteria but with only superficial erosion of the glands.

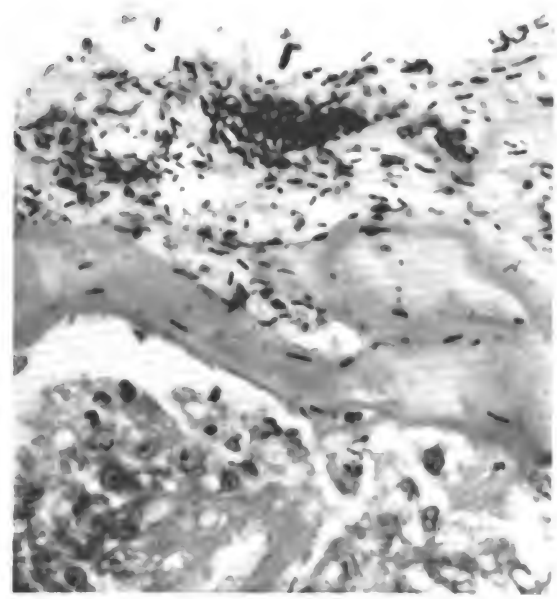

Figure 2. High power photomicrograph of the pseudomembrane with large grampositive rods characteristic of a clostridial species.

after absorption has frequently lethal action (George et al. 1978). Most human cases are seen in patients on antibiotics, after serious surgical procedures, in newborn infants, and in patients in whom, for many different reasons, immunosuppression exists. Essentially identical pseudomembranous enterocolitis can be produced experimentally in rabbits (Kata et al. 1978) and hamsters (Rifkin et al. 1978). This falcon developed acute pseudomembranous gastritis histopathologically identical to human cases. That the bird died of resulting clostridial toxemia is suggested although not confirmed by culturing the suspected etiologic agent. It is possible the falcon ingested food with large numbers of clostridial organisms, a bacterium known to multiply with great rapidity under proper circumstances and that the stress of moving led to the rapid growth of those organisms in the gastrointestinal tract resulting in pseudomembranous gastritis. It is of interest that some birds and mammals are known to carry *C. difficile* in the intestinal track (McBee 1960).

Of some clinical importance, while most clostridial species are susceptible to penicillin, *C. difficile* is sensitive only to Vancomycin. Furthermore, the oral administration of cholestyramine resin, which apparently binds the toxin in the lumen of the gut, has proven efficacious in human cases of pseudomembranous gastronintestinal disease due to *Clostridium difficile* (Kreutzer and Mulligan 1978).

LITERATURE CITED

BARTLETT, J.G., CHANG, T.W., GURWITH, M., GORBACH, S.L. AND ONDERDONK, A.B. 1978. Antiobiotic-associated pseudomembranous colitis due to toxic producing Clostridia. *N. Eng. J. Med.* 298:531-4.

GEORGE, R.H., SYMONDS, J.M., DOMOCK, F., ET AL. 1978. Identification of Clostridium difficile as a cause of pseudomembranous colitis. *Brit. Med. J.* 1:695.

GOULSTON, S.J.M. AND V.J. MCGOVERN. 1965. Pseudomembranous colitis. *Gut* 6:207-212.

KATZ, L., J.T. LAMONT, J.S. TRIER, E.B. SOUNENBLICK, S.W. ROTHMAN, S.A. BROITMAN AND S. RIETH. 1978. Experimental Clindamycin-associated colitis in rabbits. *Gastroent.* 74:246-252.

KREUTZER, E.W. AND F.D. MULLIGAN. 1978. The treatment of antibiotic-associated pseudomembranous colitis with cholestyramine resin. *The Johns Hopkins Medical Journal* 143:67-72.

MACLENNAN, J.D. 1962. The histotoxic Clostridial infections of man. *Bac. Rev.* 26:177-276.

MCBEE, R.H. 1960. Intestinal flora of some Antarctic birds and mammals. *J. Bacteriology* 79:311-312.

MURRELL, T.G.C., L. ROTH, J. EGERTON AND P.D. WALKER. 1966. Pigbel: enteritis necroticans. *Lancet* 1:217-222.

RIFKIN, G.D., J. SILVA AND R. FEKETY. 1978. Gastrointstinal and systemic toxicity of fecal extracts from hamsters with clindamycin-induced colitis. *Gastroent* 74:52-57.

Department of Biology, The Colorado College, Colorado Springs, CO 80903. Address of second author: Penrose Hospital, 2215 N. Cascade Ave., Colorado Springs, CO 88907.

Received 12 November 1983; Accepted 15 August 1984

BIOTELEMETERED DAILY HEART RATE CYCLES IN THE RED-TAILED HAWK *(Buteo jamaicensis)*

DAVID E. BUSCH, WILLIAM A. DEGRAW AND N.C. CLAMPITT

ABSTRACT - Daily fluctuations in resting heart rate (HR) were studied in a captive ♀ Red-tailed Hawk (*Buteo jamaicensis*) using radiotelemetry. HR's were recorded hourly during 10 consecutive days while the hawk was housed in an outdoor pen. Daytime HR's averaged 202 beats/min and were significantly higher than the average nocturnal HR of 134 beats/min ($P<0.001$). Maximum HR's (>200 beats/min) occurred crepuscularly, just after sunrise and before sunset.

Daily cycles of several physiological factors have long been known for a number of birds and mammals. In birds for example, marked nocturnal depression of body temperature has been demonstrated in Snowy Owls (*Nyctea scandiaca*) and Short-eared Owls (*Asio flammeus*) by Irving (1955). Odum (1941) commented on the marked changes in heart rate (HR) occuring between day and night in avian species. Smith et al. (1976) reported that telemetered HR is lower and less variable during darkness in the domestic Mallard Duck (*Anas platyrhynchos*). One method, that of telemetered HR, allows physiological study of unrestrained birds under near-natural conditions. This method has also been promoted as a suitable indicator of relative metabolic rate in homeotherms (Johnson and Gessaman 1973; Gessaman 1980).

Indications that HR can be a good relative metabolic indicator come from studies in which HR and O_2 consumption were measured simultaneously (Morhardt and Morhardt 1971; Lund and Folk 1976). Similarities between HR-ambient temperature curves and metabolism-ambient temperature curves have been demonstrated for birds such as the Burrowing Owl (*Athene cunicularia*) (Coulombe 1970) and Blue-winged Teal (*Anas discors*) (Owen 1969). Because of circulatory adjustments occurring during more intense locomotor activity, HR is only considered a valid metabolic indicator when an animal is unstressed and at rest, or exercising moderately (Jones and Wang 1976). We have used telemetered HR's to demonstrate stress in the Ferruginous Hawk (*Buteo regalis*) (Busch et al. 1978), but in order to use HR as a metabolic indicator, activity levels must be low and stress minimal.

Little of the aforementioned types of research have focused on birds of prey in spite of the emphasis on raptor conservation, rehabilitation and captive breeding. Our goal was to assess diurnal fluctuations in resting HR's of the Red-tailed Hawk via telemetry. Changes in HR were also compared with time of day and with extrinsic factors such as ambient temperature and elevation of the sun.

METHODS

The subject of this study, a ♀ Red-tailed Hawk, was considered non-releasble by rehabilitation personnel because of an unmendable broken wing. This disability did not conflict with the study's goals since the bird's feeding and perching were not affected, and since our focus was on daily variations in resting HR.

The hawk was maintained in an outdoor pen measuring 56 m^2

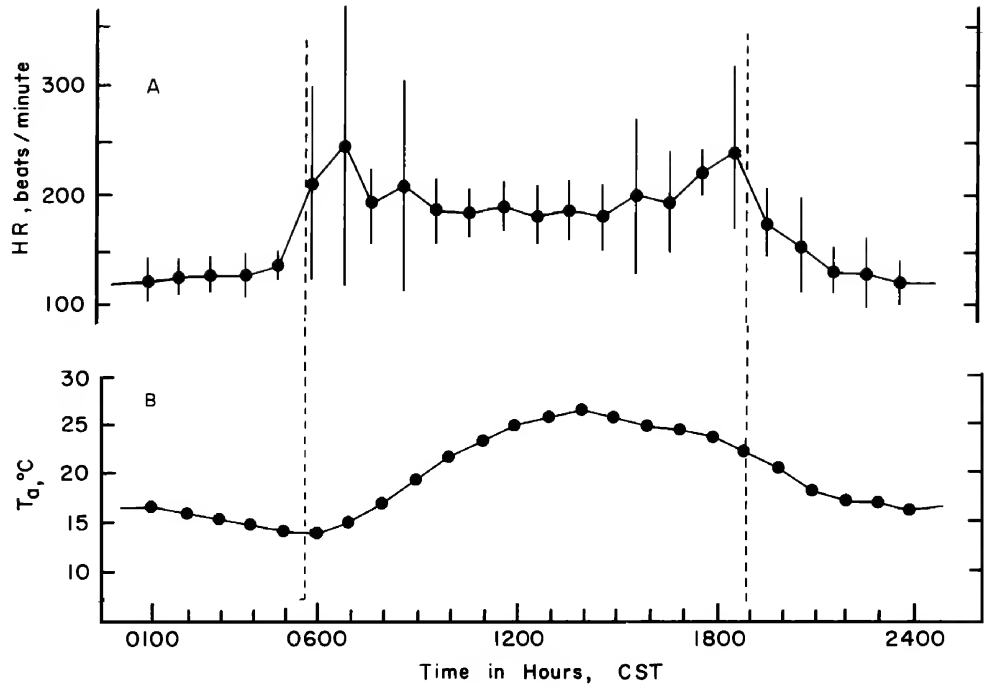

Figure 1. (A) Mean heart rates (HR) and (B) mean ambient temperatures during 10 consecutive days of recording. Vertical bars depict standard deviations for each hourly sample period (n=10 d).

located on the Allwine Prairie Preserve of the University of Nebraska at Omaha. Sources of disturbance were few at this rural site. A small building adjacent to the pen provided portholes for observing the bird, as well as electrical power and housing for the recording instruments. The desirability of such conditions was highlighted by Owen (1969) who measured significantly higher HR's in Blue-winged Teal under semi-natural conditions than under controlled laboratory conditions. Food for the hawk consisted of freshly killed laboratory rats placed in the cage at randomly selected times which did not coincide with hourly data collection.

Electrocardiogram electrodes were surgically implanted on the pleural surface of the bird's sternum through a mid-line abdominal incision, using a modification of the method of Sawby and Gessaman (1974). Leads from these electrodes provided the input to a Narco FM 110-E4 HR telemetry transmitter. The transmitter, packaged in dental acrylic and worn by the bird as a "backpack", weighed 109g with its harness. The transmitter assembly weighed 7 5% of bird's body wt (1.45 kg). This was within the 10% limit considered valid for electrocardiogram telemetry devices (Gessaman 1973).

The telemetered signal was detected with a Narco FM 1100-7 receiver. A switching device was designed to record a 2-min segment from each h of the day. This device also operated a tape recorder on which data were recorded in digital format as audible "clicks." Each click represented 1 QRS complex from the electrocardiogram (1 heart beat). High heart rates made counting audible clicks impractical so these data were coverted to an analog format using a Physiograph Cardiotach. The resulting chart records were analyzed to determine $\bar{x}$ HR for each 2-min sampling period, and to evaluate changes between hourly $\bar{x}$ HR's for more than 240 sample times. Data were collected continuously for 10 d between 9 and 18 April 1977. During this period daily $\bar{x}$ max. temp. was 24.1 ± 3.7°C (n=10), while the $\bar{x}$ min. temp. was 12.4 ± 3.1°C (n=10).

RESULTS AND DISCUSSION

The pattern of changes in $\bar{x}$ HR is displayed in Fig. 1A. The bimodality of the cycle, exemplified by 2 daytime peaks, prevented the use of sophisticated biorhythm analysis. However, simpler methods such as t-Tests are considered sufficient to demonstrate existence of daily biological cycles (Koukkari et al 1974). In this instance, one way ANOVA confirmed the existence of highly significant variation in HR ($F=6.589$; df = 23, 216; $P<0.001$). Furthermore, the diurnal $\bar{x}$ HR (202 beats/min) for the 14 h between sunrise and sunset was significantly greater than the nocturnal $\bar{x}$ (134 beats/min) (t-Test, $P<0.001$). Resting HR's were

highest in periods just after sunrise and just before sunset.

Variability (i.e., standard deviation) in instantaneous HR was greatest near sunrise and sunset (Fig. 1A). For example, the average coefficient of variation was 80% between 0600-0900 but was only 28% during mid-day (1000-1400). Bartlett's test revealed highly significant heterogeneity in variances ($P<0.001$). Hourly changes in $\bar{X}$ HR were also greatest in the early morning and late afternoon. When hourly changes in HR's during the 5 h around sunrise (0500-1000) were grouped with those during the 5 h near sunset (1500-2000), mean changes in HR for these 10 h were significantly greater ($P<0.01$) than changes during the other 14 h of the day.

Although daily metabolic or HR cycles are not unusual for raptors (Coulombe 1970), bimodal patterns such as reported herein have been described infrequently (Nastosescu et al. 1975). The adaptive value of this crepuscular HR pattern is somewhat puzzling.

Parallel changes in $\bar{X}$ HR's and $\bar{X}$ ambient temp should not be regarded as a casual relationship, despite the well-established inverse relationship between avian metabolism and air temp outside of the thermoneutral zone. There is strong evidence that metabolic rhythms are more closely linked to photoperiod (Folk 1974) and that daily changes in HR coincide somewhat with those of ambient temp only because of their common relationship to solar periodicity. The distinctly bimodal peaks we observed contrast with the curve for ambient temp (Fig. 1B).

The possibility that higher heart rates near sunrise might represent elevation of metabolic rate required to raise the bird's body temp from a slightly torpid nocturnal condition was examined using the Van't Hoff relationship. Assuming a Q_{10} equal to 2.3, we calculated that a difference of 4.95°C would be required to account for the difference between nocturnal and daytime $\bar{X}$ HR. A change in body temp of this magnitude is unlikely in view of reports of body temp cycles in large raptors (Coulombe 1970; Gessaman 1978) and would not explain the evening peak at all.

We might expect to find an explanation for the bimodal pattern in HR in *Buteo* behavior, however Red-tailed Hawks do not seem especially crepuscular in their activities in the wild. Their soaring activity is greatest near midday when thermal convective currents are most favorable (Henty 1977). For most buteos many potential prey species are crepuscular. Since the foraging success of Red-tailed Hawks has been linked to behavior of primary prey species (Stinson 1980), the possibility cannot be discounted that the HR cycle demonstrated here parallels activity patterns of prey.

ACKNOWLEDGEMENTS

This research was completed by the senior author in partial fulfillment of the requirements for the M.A. degree in Biology at the University of Nebraska at Omaha. It was made possible by the cooperation of the Raptor Rehabilitation Society, Lincoln, Nebraska, and assistance from R.A. Lock of the Nebraska Game and Parks Commission. We are particularly indebted to L. Phillips who assisted with surgery and to L. Simmons, Director of the Henry Doorly Zoo, Omaha, NE, who generously provided facilities and support equipment for the surgery.

LITERATURE CITED

BUSCH, D.E., W.A. DEGRAW, AND N.C. CLAMPITT. 1978. Effects of handling-disturbance stress on heart rate in the Ferruginous Hawk (*Buteo regalis*) *Raptor Res.* 12:(314)122-125.

COULOMBE, H.N. 1970. Physiological and physical aspects of temperature regulation in the Burrowing Owl (*Speotyto cunicularia*). *Comp. Biochem. Physiol.* 35:307-337.

FOLK, G.E. 1974. Environmental Physiology. Lea and Feibiger. Philadelphia. 452 p.

GESSAMAN, J.A. 1973. Ecological Energetics of Homeotherms. Utah State University Press. Logan 155 p.

———. 1978. Body temperature and heart rate of the Snowy Owl. *Condor* 80:243-245.

———. 1980. An evaluation of heart rate as an indirect measure of daily energy metabolism of the American Kestrel. *Comp. Biochem. Physiol.* 65A:273-289.

HENTY, C.J. 1977. Thermal soaring of raptors. *Brit. Birds* 70:471-475.

IRVING, L. 1955. Nocturnal decline in the temperature of birds in cold weather. *Condor* 57:362-365.

JOHNSON, S.F., AND J.A. GESSAMAN. 1973. An evaluation of heart rate as a monitor of free-living energy metabolism. *In:* Ecological Energetics of Homeotherms, J.A. Gessaman, Utah State University Press. Logan. 155 pp.

JONES, D.L., AND L.C.H. WANG. 1976. Metabolic and cardiovascular adaptations in the western chipmunks, genus *Eutamius*. *J. Comp. Physiol.* 105:219-231.

KOUKKARI, W.L., S.H. DUKE, F. HALBERG, AND J.K. LEE. 1974. Circadian rhythmic leaf movements; a student exercise in chronobiology. *Chronobiologia* 1:281-302.

LUND, F.L. AND G.E. FOLK. 1976. Simultaneous measurement of heart rate and oxygen consumption in Black-tailed Priarie Dogs (*Cynomys ludovicianus*). *Comp. Biochem. Physiol.* 55:201-206.

MORHARDT, J.E., AND S.S. MORHARDT. 1971. Correlations between heart rate and oxygen consumption in rodents. *Am. J. Physiol.* 221:1580-1586.

NASTOSESCU, GH., I. CEAUSESCU, GH. IGNAT, AND A. VADINEANU. 1975. Ritmul circadian al metabolismului energetic la *Anas platyrhynchos*. St. Si Cerc. Biol., Seria Biol. Anim. 27(2):131-135.

ODUM, E.P. 1941. Variations in the heart rates of birds; a study in physiological ecology. *Ecological Monographs* 11:299-326.

OWEN, R.B. 1969. Heart rate, a measure of metabolism in the Blue-winged Teal. *Comp. Biochem. Physiol.* 31:431-436.

SAWBY, S.B., AND J.A. GESSAMAN. 1974. Telemetry of electrocardiograms from free-living birds: a method of electrode placement. *Condor* 76:479-481.

SMITH, F.N., C. PETERSON AND K. THIGPEN. 1976. Body temperature, heart rate, and respiration rate of an unrestrained domestic Mallard Duck (*Anas platyrhincos domesticus*). *Comp. Biochem. Physiol.* 53:19-20.

STINSON, C.H. 1980. Weather-dependent foraging success and sibling aggression in Red-tailed Hawks in central Washington. *Condor* 82:76-80.

WOOLEY, J.B., JR., AND R.B. OWEN. 1977. Metabolic rates and heart rate-metabolism relationships in the Black Duck (*Anas rubripes*). *Comp. Biochem. Physiol.* 57A:363-367.

Departments of Biology and Chemistry, University of Nebraska at Omaha, Omaha, Nebraska 68182-0040. Current address of first author: Bureau of Reclamation, Box 427, Boulder City, NV 89005.

Received 17 May 1983; Accepted 10 April 1984

Status of a Population of Bald Eagles Wintering in Western Connecticut

STEVEN D. FACCIO AND HOWARD I. RUSSOCK

In a previous study (H.I. Russock, *Raptor Research* 13(4): 112-115, 1979) a population of 4 Bald Egles (*Haliaeetus leucocephalus*) was observed on wintering grounds in western Connecticut during the winter of 1976-1977. The eagles congregated below a hydroelectric dam on the Housatonic River. The dam's generators kept the otherwise frozen river open and killed or injured large numbers of fish which the eagles preyed upon. This paper presents the results of subsequent observations made during the winter of 1982-1983 on the same population of eagles which grew to 17 individuals.

Eagles were observed in the vicinity of the Shepaug Hydroelectric Dam, Housatonic River, approximately 4.6 km north of Newtown, Connecticut. Above the dam, and created by it, is Lake Lillinoah with a surface area of 769 ha. Directly west, across Lake Lillinoah, is the Upper Pauggessett State Forest extending for 3 km north along the western shore of the lake. On the south side of the river, below the dam, is a large privately owned wooded hillside where eagles congregated. North, across from the hillside, is a hydroelectric plant owned by Connecticut Light and Power Company.

Most observations were made from the top of the dam and from a canvas blind constructed on the south side of the river, approximately 25 m from a frequent perching area. Other observations were made from a road running parallel to the north side of the river and from several locations northwest of the dam (when attempting to determine roosting sites). Observations were made with field binoculars (7x35) and a 600 mm photographic lens and were results dictated into a taperecorder or handwritten. A total of 178 h of observation were made between 8 December 1982 and 8 April 1983. Trips were made to the dam on 52 separate days, 34 of which resulted in sighting of eagles.

The first eagle observed was on 3 January 1983; 9 observation days in December did not result in any sightings. Eagles were last observed on 24 March 1983; during 6 observation days in late March and early April none were seen.

Due to unusually mild weather, the Housatonic River remained virtually free of ice during the entire winter. Therefore, the departure of eagles could not be correlated with the opening of the river in spring as it was during the winter of 1976-1977. It was not determined if the greater availability of open water elsewhere affected the number of eagles wintering in the vicinity of the Shepaug Dam. However, due to the abundance of fish at the dam, it is likely that all eagles wintering in the area frequented the dam.

Seventeen individuals were positively identified using plumage characteristics and other outstanding features;

10 were adults and 7 immature. Eight (4 adults, 4 immatures) were observed frequently from early January to early or mid-March. Two other immatures were observed between 6 and 24 February 1983. Seven others (5 adult, 2 immatures) were seen on 1 or 2 observation days each, between 13 January and 12 March 1983.

Night Roosts — Three night roosts were tentatively 2.5-7.5 km north and northwest of the Shepaug Dam. All 3 were located in undeveloped mixed hardwood forest. The first 2 sites were located by direct observation of eagles leaving or returning in early morning and early evening, respectively. The third was located with a police scanner by tracking a radio-tagged eagle.

Breeding grounds — The 17 eagles wintering in the vicinity of the Shepaug Dam can be divided into 2 groups, 8 observed throughout the winter and 9 observed over a period of 1 to 18 d. It is reasonable to assume that the latter group is made up of transient birds. Three of these have been traced to breeding areas in Maine. Two immatures observed only during February were identified by leg bands as hatch year birds from Maine. A third immature, observed on 1 d in February, had both leg bands and a backpack transmitter which identified it as coming from a nest in the Cobscook Bay area of the Main coast. Two others (1 adult, 1 immature), seen on 1 or 2 d each, also had leg bands, but could not be further traced.

There is no direct evidence of an active nest in the area. However, 7 of the 8 eagles observed throughout the winter could be divided into 2 groups which virtually always moved as separate units. One group consisted of 2 adults and 1 immature and the other group consisted of 2 adults and 2 immatures. This suggests that there were 2 family groups. The senior author observed a single adult on 3 separate occasins during the first week of June 1983, approximately 7 km north of the Shepaugh Dam.

Feeding — Eagles arrived at the dam area 5-15 min before sunrise; they remained perched until the hydroelectric plant started operation at 0700 when they began feeding on fish killed or injured by the plant's turbines. Feeding continued for 1-3 h after which the birds perched or soared over the hills on the south side of the river. Feeding often resumed in early afternoon before the birds returned to their roosts.

Eagles were observed making dives to the river to catch fish on 232 occasions, 170 (73%) of which were successful. Adults were successful on 103 (75.7%) of 136 attempts while immatures were successful on 67 (69.8%) of 96 attempts (NS, X^2 Test). Fish caught included trout (*Salvelinus* spp.), bass (*Micropterus* spp.), catfish (*Ictalurus* spp.), and shiner (*Notropis* spp.).

We thank Connecticut Light and Power Company for allowing access to their property. We also thank Lawrence Fisher, Janet Mitchell and Stewart Mitchell for their help and personal observations of Bald Eagles in western Connecticut and Francis Gramlich, NSBERT, for his help in tracing several eagles to Maine. Dr. Frank Dye and Dr Susan Maskel, Western Connecticut State University, commented on an earlier version of this manuscript.

Department of Biological and Environment Sciences, Western Connecticut State University, Danbury, Connecticut 06810.

Received 8 March 1983; Accepted 10 May 1984.

* Please send reprint requests to H.I. Russock

Nest Defense by Northern Harriers Against the Coyote in Southwestern Idaho

LEON R. POWERS, TIMOTHY H. CRAIG AND JOHN MARTIN

Predation on Northern Harrier (*Circus cyaneus*) by Striped Skunk (*Mephitis mephitis*), Badger (*Taxidea taxus*), foxes (*Fulpes* sp.) and Mink (*Mustella vision*) has previously been reported. (Craighead and Craighead 1956; Hamerstrom 1969; Watson 1977). Although Murie (1940) reported that Coyotes (*Canis latrans*) prey on the Short-eared Owl (*Asio flammeus*), an ecological equivalent of the Northern Harrier, we are not aware of reports of Coyote predation on Northern Harriers. Herein we report several Northern Harrier — Coyote interactions observed during 1981 in the Snake River Birds of Prey Study Area in southwestern Idaho.

On 29 March at 1020, T.C. observed a pair of nesting harriers perched in a small tree (*Crataegus* sp.) near a spring bordering the Snake River. Riparian habitat surrounded the spring for a distance of 15 m with senescent reed (*Phragmites communis*) and stinging nettle (*Urtica* sp) the predominant vegetation. Beyond the spring, big sagebrush (*Artemesia tridentala*) and June grass (*Bromus tectorus*) covered the nearby canyonside. Shortly, the female harrier flew from the tree followed by the male, and both began emitting a call usually associated with agnostic displays. The male then started diving repeatedly at the edge of the riparian growth. By the male's changing position it was obvious that the object of his dive was moving toward the center of the riparian vegetation. As the hawk completed a dive, a Coyote rose on its hind legs above the vegetation and snapped its jaws at it. The Coyote again attempted to grab the harrier, and then stopped with his back visible. It appeared that it was moving its head near the ground as if eating. The female harrier circled and called overhead while the male con-

tinued to call and dive, although not as closely. After about 5 min, T.C. approached the spring and the coyote fled with the male harrier in close pursuit, diving with both feet swung forward attempting to grab the coyote. A single, pale-blue, harrier egg was found in the nest at the spot where the coyote had appeared to be eating. Both harriers circled and called over the human intruder but neither dived. A single adult male harrier was observed near the nest area on 24 April but on 2 subsequent visits no birds were seen. On 7 July the nest was visited again and only a few bits of egg shell were found; however, no harriers were present.

On 30 May at 1146 L.P. observed a male harrier escort a Golden Eagle (*Aquila chrysaetos*) from the harrier's territory. The harrier circled back toward its nest in a shallow undulating flight and began to vocalize and dive at something on the sagebrush slope above the nest site. As the male continued its vigorous dives, the object of the attack, a Coyote, appeared. A female harrier soon began circling over the area, occasionally making shallow dives at the Coyote. Shortly, a second male harrier flew into the area from a neighboring nesting territory to the east and joined the pair. The second male appeared to "sky dance" (Hamerstrom 1969) around the female at first but soon began to vocalize and dive at the Coyote also. The Coyote, followed by the defending hawks, gradually moved out of view toward the neighboring harrier territory. At 1155 a male harrier reappeared from the east and soared above the original harrier's territory.

Later that day at the same harrier territory, a male flew across the river from its nest area and dove several times at a Coyote that trotted eastward. After 1 to 2 min the harrier veered off, perched on a sagebrush briefly and then flew at an angle away from the Coyote and intercepted a second male harrier which was approaching the Coyote from the northeast. The first male briefly chased the invading hawk which attempted to dive at the Coyote. Soon, the first harrier flew back toward its territory and began to hunt. Within 5 min he captured a small prey item and delivered it to his mate at the nest across the river. When we visited the nest on 7 June, 1 egg and 2 nearly-hatched nestlings were found. Twenty-seven days later on a second visit the nest had been destroyed and only pin feathers of juveniles remained. The adjacent harrier nest to the east successfully fledged at least 3 young.

J.M. frequently saw Coyotes in the vicinity of harrier nests on the study area, and observed both male and female harriers, individually and jointly, diving at Coyotes. More often the male was the lone defender. As in the previously described observations, J.M. also observed a Coyote leap into the air after a defending adult male and at times observed several harriers cross well defined territorial boundaries to pursue a Coyote. Newton (1979) reports such communal nest defense among Marsh Harriers (*Circus aeruginosus*). In one location J.M. found a Coyote den at one end of a large marsh which contained 7 harrier nests. Five of those 7 nests failed, and 3 showed evidence of Coyote predation.

Although eye-witness accounts of predation at raptor nests are not common, our observations indicate that Coyotes do prey on Northern Harrier nests, especially in desert areas, perhaps where sparse riparian habitat attracts both animals. Furthermore, our report suggests a danger of leading this predator to harrier grounds nests by investigator scent trails (Fyfe and Olendorff 1976) as reported by Craighead and Craighead (1956) for a farm dog (*Canis familiaris*).

We thank Drs. F. and F.N. Hamerstrom for helpful comments on the manuscript.

LITERATURE CITED

CRAIGHEAD, F.C. AND J.J. CRAIGHEAD, JR. 1956. Hawks, owls and wildlife. Harrisburg, Stackpole Co.

FYFE, R.W. AND R.R. OLENDORFF. 1976. Minimizing the dangers of nesting studies to raptors and other sensitive species. Canadian Wildlife Service, Occasional Paper Number 23.

HAMERSTROM F. 1969. A harrier population study. Pages 367-383. *In* J.J. Hickey, (Ed.). Peregrine Falcon Populations: their biology and decline. University of Wisconsin Press, Madison, Milwaukie, and London.

MURIE, A. 1940. Ecology of the coyote in Yellowstone. U.S. Dept. Int., Natl. Park Serv., Fauna Ser. 4.

NEWTON, I. 1979. Population ecology of raptors. Buteo Books. Vermillion, S.D.

WATSON, D. 1977. The hen harrier. T. and A.D. Poyser, Ltd., Berkhamstead, Herts., England.

Department of Biology, Northwest Nazarene College, Nampa, Idaho 83651.Address of second author: Box 1, Lee Creek Road, Leadore, Idaho 83464. Address of third author: 6702 East 950 South, Huntsville, Utah 84317.

Received 26 December 1983; Accepted 10 May 1984

NEWS AND REVIEWS

BEHAVIOR OF FLEDGLING PEREGRINES BY STEVE K. SHERROD; drawings by Karen Lynn Allaben-Confer. 1983. Fort Collins, Pioneer Impressions. xi + 202 pp., 59 figures, 23 tables. Price $10.00. Available from the Peregrine Fund, Inc., Ithaca, New York.

Peregrine Falcons are renowned for their spectacular aerial feats. How they develop this unique behavior is unfolded as 4 broods of fledglings, 2 broods from Australia and 2 from Greenland, are followed from first flight to dispersal. The book's sequ-

ence of chapters follows the development of fledgling behavior. Initial sections cover simple perch-to-perch flight behavior, followed by behavioral descriptions of soaring, stooping, pursuits of parents and siblings, pursuits of inanimate and animate objects, play, and development of the ability to kill. Later, types of food transfers from adults to offspring and various types of aggression are described. The final section covers the length of post-nestling dependency, including a discussion of stimulus for dispersal and parental care during migration.

The 1 overriding observation that leaps out to the reader is the aggressiveness of the young. Sherrod states "Aggression is a component common to the behavioral repertoire of the peregrine, and it is incorporated into many of the displays of this bird". A common phrase "don't bite the hand that feeds you" is scoffed at by fledglings. Parents are bitten, footed, bumped off their perches and chased relentlessly by juveniles seeking food — even when there is none to be had. Such aggressiveness provides the basis for the author's reinterpretation of the "luring" behavior reported by early observers of peregrine behavior. It has been thought that when adults flew by their nests with prey they were "luring" their young to fly from the nest. The author, however, provides many observations to indicate that adults are simply reluctant to land because they "fear" being rushed by thier young, bitten, footed or pushed off the ledge itself.

In addition to fledgling behavior of wild peregrines, extremely valuable behavioral comparisons were made with broods of fledglings without parents that are "hacked" from artificial nests. Most behaviors observed in wild young also recurred in hacked young but distinctions were present. For example, "Although hacked fledglings instinctively recognize other raptors, wild offspring probably learn which predators are an immediate threat in their natal territory by observing the defensive behavior of their parents".

I found this book valuable because it 1) provides a wealth of background information for future comparative behavioral studies of congeners, 2) provides a clear picture of the development of fledgling peregrine behavior (and associated adult behavior) for people who have never had the opportunity to observe nests, 3) provides descriptions of behavior that fill in gaps of knowledge for even experienced observers who are not fortunate enough to observe, uninterruptedly, fledgling behavior from first flights to dispersal and 4) focused attention on aspects of my own behavioral observations of peregrines that I did not put into context until after reading the book. For example, while I watched shorebirds at high tide on 3 November 1975 at the northern end of Humboldt Bay, California, 2 peregrines flew by and the adult male captured a small shorebird, Western Sandpiper (*Calidris mauri*) size, killed it, and then dropped it 10 m and recaught it Meanwhile the female struck a shorebird that fell into the water She made several passes at it but was unable to pick it up. When the 2 falcons rejoined in flight the male dropped his kill to the female below him but she failed to catch it. Moments later she captured a Willet (*Catoptrophorus semipalmatus*) sized shorebird but then dropped it into the bay. The male then caught another small shorebird, carried it out over the bay, accompanied by the female and heading south where they eventually disappeared. After reading Chapter 9, it occurred to me that what I may have observed was parental care during migration or, continuation of the adult pair bond after leaving the nesting cliff, although I could not be sure if the female was an adult.

Numerous format irregularities were distracting. When I first opened the book I was immediately struck by the contrast in type sizes, and then by the narrow margins. The feeling of being squeezed was further compounded by the narrow bar widths in Figures 3, 26a & b, 33a-e, and 56. Table and figure captions in the text are inconsistent with those given at the beginning of the book The drawings ranged from excellent to extremely poor. (Fig. 48 looks more like a Potoo (Nyctibius) than a Peregrine. Some figures seem irrelevant (Figs. I, 20, 21) and 1 figure (38) appears to have been printed upside down. The eyes are virtually obscured in all Peregrine drawings. In defense of the book, however, all drawings do illustrate what is being demonstrated behaviorally.

The author seemed (understandably) reluctant to summarize much of his data because juvenile Peregrines show wide variation in the initiation of a behavior and its expression. Instead, numerous bar graphs are presented to visually depict the variation and midpoint of the data. A valuable addition would be a single timeline, summarizing when the mean onset of each behavior occurs in terms of fledgling age or time on the wing since first flight.

Despite a few shortcomings in the format, I highly recommend the work. It has immediate appeal to raptor biologists for behavioral descriptions. There is also a broader appeal because Sherrod makes numerous behavioral correlations between the offspring of Peregrines and the offspring of mammalian carnivores. — DOUGLAS A. BOYCE JR.

R A P T O R R E S E A R C H
A QUARTERLY PUBLICATION OF THE RAPTOR RESEARCH FOUNDATION, INC.

Raptor Research (ISSN 0099-9059) welcomes original manuscripts dealing with all aspects of general ecology, natural history, management and conservation of diurnal and nocturnal predatory birds. Send all manuscripts for consideration and books for review to the Editor. Contributions are welcomed from throughout the world, but must be written in English.

INSTRUCTIONS FOR CONTRIBUTORS: Submit a typewritten original and two copies of text, tables, figures and other pertinent material to the Editor. Two original copies of photographic illustrations are required. *Raptor Research* is published in a double-column format and authors should design tables and figures accordingly. **All submissions must be typewritten double-spaced** on one side of 8½ x 11-inch (21½ x 28cm) good quality, bond paper. Number pages through the Literature Cited section. The cover page should contain the full title and a shortened version of the title (not to exceed 30 characters in length) to be used as a running head. Author addresses are listed at the end of the Literature Cited section. Authors should indicate if present addresses are different from addresses at the time the research was conducted. When more than one author is listed, please indicate who should be contacted for necessary corrections and proof review. Provide an abstract for each manuscript more than 4 double-spaced typewritten pages in length. Abstracts are submitted as a separate section from the main body of the manuscript and should not exceed 5% of the length of the manuscript. Acknowledgements, when appropriate, should immediately follow the text and precede the Literature Cited. Both scientific and common names of all organisms are always given where first appearing in the text and should conform to the current checklists, or equivalent references, such as the A.O.U. Checklist of North American Birds (6th ed., 1983). Authors should ensure that all text citations are listed and checked for accuracy. If five or fewer citations appear in the text, place the complete citation in the text, following these examples: (Brown and Amadon, Eagles, Hawks and falcons of the World. McGraw-Hill, New York. 1968), or Nelson (*Raptor Res.* 16(4):99, 1982). If more than five citations are referenced, each should include author and year (e.g., Galushin 1981)), or in a citation with three or more authors, the first author and year (e.g., (Bruce et al. 1982). Citations of two or more works on the same topic should appear in the text in chronological order (e.g., (Jones 1977, Johnson 1979 and Wilson 1980). Unpublished material cited in the text as "pers. comm.," etc., should give the full name of the authority, but must not be listed in the Literature Cited section. If in doubt as to the correct form for a particular citation, it should be spelled out for the Editor to abbreviate.

Metric units should be used in all measurements. Abbreviations should conform with the Council of Biology Editors (CBE) Style Manual, 4th ed. Use the 24-hour clock (e.g., 0830 and 2030) and "continental" dating (e.g., 1 January 1984).

Tables should not duplicate material in either the text or illustrations. Tables are typewritten, **double-spaced throughout**, including title and column headings, should be separate from the text and be assigned consecutive Arabic numerals. Each table must contain a short, complete heading. Footnotes to tables should be concise and typed in lower-case letters. Illustrations (including coordinate labels) should be on 8½ x 11-inch (21½ x 28cm) paper and must be submitted flat. Copies accompanying the original should be good quality reproductions. The name of the author(s) and figure number should be penciled on the back of each illustration. All illustrations are numbered consecutively using Arabic numerals. Include **all** illustration legends together, typewritten **double-spaced**, on a single page whenever possible. Line illustrations (i.e., maps, graphs, drawings) should be accomplished using undiluted india ink and designed for reduction by 1/3 to ½. Drawings should be accomplished using heavy weight, smooth finish, drafting paper whenever possible. Use mechanical lettering devices, pressure transfer letters, or calligraphy. Typewritten or computer (dot matrix) lettering is **not** acceptable for illustrations. Use of photographic illustrations is possible but requires that prior arrangements be made with the Editor and the Treasurer.

A more detailed set of instructions for contributors appeared in *Raptor Research*, Vol. 18, No. 1, Spring 1984, and is available from the Editor.

NON PROFIT ORG.
U.S. POSTAGE
PAID
PERMIT #66
PROVO, UTAH